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ILLINOIS NATURAL HISTORY SURVEY

YELLOW PERCH SUPPLY AND LIFE HISTORY

F-95-R-1-4

Final Report
to
Illinois Department of Conservation

Center for Aquatic Ecology

J. Ellen Marsden, Wayne A. Brofka, Daniel B. Makauskas, and William H. Horns

Illinois Natural History Survey
Lake Michigan Biological Station
Zion, IL 60099

August 1993

Aquatic Ecology Technical Report 93/12

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Lake Michigan Biological Station
Center for Aquatic Ecology
Illinois Natural History Survey

Submitted to
Division of Fisheries, Illinois Department of Conservation
in fulfillment of the reporting requirements of
Federal Aid Project F-95-1-4

J. Ellen Marsden	David P. Philipp, Head
Illinois Natural History Survey	Center for Aquatic Ecology

August 1993

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Project Summary

This document serves as a final report for a three year study conducted by William Horns and funded by the Illinois Department of Conservation from July 1, 1988 to June 30, 1991. A fourth year of the study was subsequently funded by IDOC from July 1, 1991 to June 30, 1992, and conducted by Ellen Marsden and William Horns. The original study comprised objectives 1 - 4 (study 101 and study 102); objective 5 (study 103) was added in segment 3 of the project..

Study 101: Adult Abundance and Movements

Job 1: Obtain, rig, and maintain a suitable boat

Objective: To obtain and rig a boat suitable for collecting adult yellow perch using drop nets and other gear and for collecting young-of-year yellow perch using plankton nets, high speed samplers, and trawls.

Progress: The research vessel *Sculpin* was obtained and rigged with a trawl frame to enable deployment of fyke nets and an otter trawl to collect yellow perch. A Boston whaler (the *Perch Search*) was rigged with a frame on the forward deck to mount a plankton net for sampling in the top meter of water.

Job 2: Develop a study design

Objective: To develop a strategy for collecting, marking, and recapturing yellow perch that will yield the desired results.

Progress: Preliminary sampling was conducted at various sites along the Illinois shoreline to determine optimum areas for sampling adult and juvenile yellow perch. Waukegan, Camp Logan, and Glencoe were established as primary sampling sites for adult perch, with collections taking place at 5, 10, and 15m. Tagged fish were recovered throughout the year using fyke nets and trawls. Data were also obtained from anglers, commercial fishermen, and other state agencies.

Job 3: Mark and recapture adult yellow perch

Objective: To recapture as many tagged yellow perch as possible from populations tagged in previous years of this study.

Progress: In the first three years of the study, 55,346 perch were marked using individually numbered Floy tags. By the end of the fourth segment, we had recovered 544 tagged fish (0.98% of the number tagged) using fyke nets and trawls.

Job 4: Obtain data from external sources

Objective: To augment our database with information obtained through other individuals and agencies, focusing on the capture of tagged fish by anglers, commercial fishermen, and state agencies.

Progress: 1,004 tagged perch (1.82% of the fish tagged) were recovered from external sources during the study.

Job 5: Determine ages of captured fish

Objective: To determine the ages of captured yellow perch.

Progress: All fish sub-sampled during fyke netting were aged using the otoliths.

Job 6: Analyze and report data

Objectives: (1) To derive annual estimates of the adult population size of yellow perch in the northern half of the Illinois waters of Lake Michigan during 1992, and (2) to derive estimates of how many adult yellow perch migrate into and out of the study area in 1992.

Progress: Lincoln index and Jolly-Seber estimates of the population of fish near Waukegan in spring were derived. The variances on these estimates indicate that the population is not discrete, i.e., it mixes with the whole lake population sufficiently to invalidate the method of determining absolute abundance through mark-and-recapture.

Study 102. Young-of-the-Year Abundance and Distribution

Job 1: Collect newly hatched yellow perch.

Objective: To quantify annual production of young-of-year yellow perch in our study area

Progress: Larval yellow perch were collected using a 363 micron mesh plankton net pushed for 0.5 miles just below the surface after sunset. Sites for sampling larval yellow perch were established at Waukegan in 5 and 10m of water. Young-of-year perch were sampled off Camp Logan and Waukegan using a 16' trawl.

Job 2: Determine numbers of young-of-year yellow perch eaten by alewives.

Objective: To determine the numbers of young-of-year yellow perch in the guts of alewives.

Progress: Gill nets set at night were used to collect alewives. In 1989 collections of alewives were not made until very late in the yellow perch spawning season. In 1990 collections were not possible because of mechanical problems with our research boat during the spawning season. In 1991 larval yellow perch abundance was extremely low (Job 1). No attempt was made to quantify predation by alewives.

Job 3: Determine ages and lengths of captured yellow perch

Objective: To determine the ages and lengths of young-of-year yellow perch collected in Job 1 and, to the extent possible, job 2.

Progress: Considerable effort was expended in trying to age young-of-year yellow perch using daily growth increments on otoliths. From our data and in consultation with other experts in fish aging, we determined that daily ages could not be determined. The data from the otoliths were apparently particularly confounded by the effect of cold-water upwellings which affected the growth of 0+ aged perch.

Job 4: Analyze and report data.

Annual production of young-of-year yellow perch is reported in this document.

Study 103. Predation by Yellow Perch on Chinook Salmon

Job 1: Collect adult yellow perch

Objective: To estimate, for a period of one week following stocking, the incidence of chinook salmon in stomachs of yellow perch near where chinook salmon are stocked.

Progress: We attempted to document predation by yellow perch on young chinook salmon stocked into Waukegan Harbor, Illinois, in 1989 and 1990. 230,000 young chinook salmon were stocked on May 30, 1989 and 175,000 were stocked on May 15, 1990. Each year the average length of stocked salmon was 92 mm. In 1989, 492 yellow perch were collected from Waukegan Harbor within 48 hours of stocking. All stomachs were examined and no salmon were present. An additional 883 yellow perch from the vicinity of Waukegan Harbor were examined during the following weeks and one 196 mm individual contained one 44 mm Pacific salmon. In 1990, 35 adult female yellow perch averaging 220 mm in total length were collected from Waukegan Harbor within 30 hours of stocking. The largest of those fish (292 mm) contained one 65 mm Pacific salmon. The lengths of the two Pacific salmon recovered from yellow perch stomachs in 1989 and 1990 (44 mm and 65 mm) were far below the average length of stocked chinook salmon each year (92 mm). These results are inconclusive, but are consistent with a low level of highly size-related predation on young chinook salmon.

EXECUTIVE SUMMARY

The purpose of this study was to estimate the population size of yellow perch in Lake Michigan and describe the movements of perch into and out of Illinois waters. This information is important for predicting the impact of commercial and sport fishing harvests on populations of this popular fish species. Adult yellow perch were collected using fyke nets and trawls and were tagged with individually numbered Floy tags. All fish were measured and sexed, if possible; subsamples of fish were aged using otoliths. Fish were recaptured using fyke nets and trawls, with effort focused at Camp Logan, Waukegan, and Glencoe along the northern portion of the Illinois shoreline. Tags were also returned to us by anglers, commercial fishermen, and state agencies. We conducted annual collections of larval perch in spring and young-of-year perch in fall to evaluate the abundance of these two life stages, and to determine whether their abundance could be used to predict subsequent year class strength. Two additional objectives were included to determine whether alewife consume larval perch, and whether adult perch consume newly stocked chinook salmon. Both of these studies were experimental in nature, as no preliminary data had been collected to predict whether the studies were feasible.

Objectives:

1) Estimate the size and age structure of the adult yellow perch population in south-western Lake Michigan
2) Quantify movements of yellow perch into, out of, and within the study area each year.
3) Estimate annual production of young-of-year yellow perch in our study area (and describe their temporal and geographic distribution).
4) Describe and quantify alewife diet during the weeks when vulnerable yellow perch (i.e., less than 9 mm in length) are present.
5) Estimate the incidence of chinook salmon in stomachs of yellow perch in the vicinity of chinook salmon stocking for a period of one week following stocking.

Conclusions:

- **Tagging studies indicated that yellow perch tend to return to the same site in spring year after year for spawning in the Illinois waters of Lake Michigan.**
- **Adult yellow perch tagged in Illinois in spring wandered widely in summer and fall. Perch tagged in Waukegan were recaptured as far away as Bailey's Harbor, WI, and Manistee, MI.**
- **Perch tagged near Waukegan tended to wander north and were vulnerable to the Wisconsin fishery.**

These observations indicate that stocks of yellow perch which spawn in Illinois waters wander into other state jurisdictions later in the year, where they become vulnerable to anglers and commercial fishermen. The data also suggest that genetically differentiated stocks of yellow perch may exist due to reproductive separation. Clearly, it is important for the effective management of yellow perch in Illinois to determine whether locally distinct stocks exist. This objective can be achieved with the use of modern genetic techniques.

- **Calculation of the abundance of adult yellow perch using mark-and-recapture data yielded variances much higher than the abundance estimates.**

The mark-and-recapture study was limited by the size of the system (Lake Michigan) and the potential existence of local, discrete stocks. This result indicates that the assumptions underlying the abundance estimation methods were violated, primarily the assumption of no immigration or emigration from the tagged population. Our data on yellow perch movements show that adult perch wander widely throughout the lake. Although we tagged over 55,000 perch and obtained data on over 1,500 recaptured perch, these numbers are only a tiny fraction of the population of perch in the entire lake. We conclude that the only method to accurately assess the population of yellow perch in Lake Michigan using tag-and-recapture methods would be to conduct a massive multi-agency, lake-wide tagging and recapture effort. Given the extremely high cost in terms of time and money of such a study, the effort would be better expended in obtaining *relative* estimates of abundance using catch per unit effort data at index stations along the shoreline. This study provides the first seven years of data for such a database. Alternatively, once the stock structure of yellow perch in Lake Michigan is known, intensive tagging efforts could be conducted which focus on discrete stocks in spring only.

- **The study suggested that trawl catches of young-of-year perch could be used as an indication of year class strength, although more supporting data are needed.**

- **Larval abundances appeared to be highly influenced by factors such as wind and water temperature, and were not dependable for predicting year class strength.**

- **In the past 12 years, year class abundance of adult yellow perch has shown a four-to-five year cycle.**

Each strong year class is followed by a very weak year class, with successively increasing year classes culminating in a new peak four to five years after the last one. The strong year classes sustain the fishery during periods of weak year class production. The next strong year class should be produced in 1992 or 1993. However, young-of-year catches declined from 1988 to 1990 ~~1989~~, and no young-of-year perch were caught in 1991 ~~1990~~ or 1992 ~~1991~~ by ourselves, WDNR, or USF&WS. The absence of a strong year class, suggested by these data, will result in poor fishing in the mid-1990's until two years after a good year class is produced.

- **Tag return data must be evaluated based on the source of the data.**

Sport fishermen returned many tags, but the data reliability was low. Inaccuracies could only be detected when the length measurements were lower than on the tagging date, or the location of the recapture was not within the Lake Michigan watershed. Commercial fishermen do not tend to record details of capture date, location, or fish length, and many tags are missed during processing and are subsequently returned by fish processing houses.

- **Male perch dominated the spring collections due to their spawning behavior - males move into shallow water early in spring and remain there throughout the season, while females come inshore only to spawn, and then depart.**

- **Male yellow perch caught during this study in the 1980s were smaller, at a given age, than perch caught at the same sites by other researchers in the 1970s.**

This change in size indicates that perch grew more slowly in the 1980s, likely due to the increase in population size.

- **The sex ratio of yellow perch was skewed in favor of males at all seasons during all years of the study. The causes of this imbalance are not known.**

- **No attempt was made to quantify predation by alewives on larval yellow perch.**

- **1,410 yellow perch were collected within a few weeks of chinook salmon stocking; two stomachs contained a single Pacific salmon each.**

INTRODUCTION

Yellow perch (*Perca flavescens*) are the most popular angler-caught fish in Lake Michigan, and they continue to support an important commercial fishery in Illinois waters. Perch were abundant in Lake Michigan in the 1950's and early 1960's, but in 1965 the population crashed (Figure 1). Recovery of the fishery began in the late 1970's, and by the early 1980's the sport and commercial fishery had expanded dramatically (Wells and McLain 1973). The estimated annual catch by sport fishermen in Illinois waters alone tripled from 600,000 in 1979 (Muench 1981) to 1.8 million in 1986 (Horns and Gorden 1988). Commercial fishing for yellow perch in southern Lake Michigan has also expanded: in Illinois the harvest increased from 46,000 pounds in 1979 to 156,000 pounds in 1986 due to quota changes (Hess 1988), and in Indiana the harvest increased from 92,000 pounds in 1978 to 1,304,000 pounds in 1987 (Brazo 1988). Because of a lack of basic information about the factors that affect population size, it is not clear whether the recent abundance of yellow perch can be sustained. Little information exists on the current size of the fishable yellow perch stock or about movements of perch in Lake Michigan. The 1983 and 1988 year classes of yellow perch were strong (Bruch at al. 1985, this report), and were major contributors to the recent yellow perch fishery. However, in recent years (1990-1992) the population of young-of-year perch has been minimal or absent in sampling gear deployed by ourselves, the Wisconsin Department of Natural Resources (WDNR), ~~Wisconsin~~ Indiana Department of Natural Resources (IDNR), the University of Michigan, and the U. S. Fish and Wildlife Service (Great Lakes Fishery Commission annual meeting, 1993).

Species management in a large ecosystem such as Lake Michigan cannot be conducted effectively without an understanding of the population structure and dynamics of the fish species. Estimates of yellow perch population size and age structure and movements into and out of Illinois waters are needed in order to predict the impact of steadily increasing sport and commercial harvests. Adequate estimates of yellow perch abundance and movements in Lake Michigan have not been made, although studies have been conducted in the southern basin of Lake Michigan by the WDNR (e.g., Bruch et al. 1985) and Indiana Department of Natural Resources. In addition, no information exists to clearly define whether the yellow perch population in Lake Michigan is composed of one or many stocks. Consequently, the fish are managed as a single, panmictic population. This strategy could have negative consequences for the fishery if stocks which reproduce in one state tend to wander into other states during the summer and fall. Different state fishing regulations would have the potential to allow depletion of reproductive stocks which supply the summer fishery for another state.

The purpose of this study was to address the need for information on yellow perch populations. Specifically, the objectives were stated as follows:

1) Estimate the size and age structure of the adult yellow perch population in south-western Lake Michigan
2) Quantify movements of yellow perch into, out of, and within the study area each year.

3) Estimate annual production of young-of-year yellow perch in our study area (and describe their temporal and geographic distribution).
4) Describe and quantify alewife diet during the weeks when vulnerable yellow perch (i.e., less than 9 mm in length) are present.
5) Estimate the incidence of chinook salmon in stomachs of yellow perch in the vicinity of chinook salmon stocking for a period of one week following stocking.

These objectives were approached by conducting an extensive mark-and-recapture study along the northern shoreline of the Illinois waters of Lake Michigan. The approximate size of the sport harvest over the past seven years is known from creel survey data (Brofka and Marsden 1993) and the commercial catch is reported directly to the Illinois Department of Conservation. With the addition of (a) an estimate of population size and its length and age structure, and (b) estimates of movements into and out of the area, we will have a basis for determining how present harvests are affecting the size and age distributions of the population and whether or not the harvests can be sustained. In addition, we conducted annual sampling of larval and young-of-year yellow perch to describe their temporal and geographic distribution and determine whether the abundance of these life stages could be used to predict year class strength. This report also includes data from related studies on adult, larval, and young-of-year perch conducted in 1986-1988 and in 1993.

METHODS

Mark-and-recapture study

Adult yellow perch were collected in 1988 through 1993 using fyke nets and trawls. Tagged fish were recaptured during our own sampling efforts and also by anglers, commercial fishermen, and state agencies.

Sampling sites

In 1988 sampling was done on a limited scale using overnight fyke net sets once per week during the month of August. Two sites were used (Figure 2). The first site, identified as "S Waukegan", was located in 5-6 meters of water approximately 0.3nm (0.46 km) off the site of the old US Steel wire mill. The site straddled the intake pipe for the now non-existent plant. The second site, identified as "N. Chicago", was located in 10 meters of water over the crib to a water intake pipe about half a mile (0.77 km) south of the wire mill site. Both sites had a mixed sand and rock bottom except for the intake pipes which are armored in limestone blocks.

In 1989 the majority of the sampling effort was focused at the site south of Waukegan. Several other sites were investigated, two of which became primary sites for our later work. The "Camp Logan" site is due east and slightly south of the Lake Michigan Biological Station in the Illinois Beach State Park (north unit). The bottom substrate is primarily sand with some smooth stones scattered throughout. Fyke nets were also set at two sites offshore from Tower Road in Glencoe ("S Tower" and "N Tower"), where the bottom substrate is a combination of sand, rock and bed rock. Camp Logan became our primary sampling site in subsequent years, and the Glencoe site was sampled intensively in 1990 and 1991. Two fyke net sets were made north and south of the Zion Nuclear Electrical Generating Plant ("Zion Nuke") on primarily sand substrate. Trawling was begun north of Waukegan, on sandy substrate, and this became our primary trawling site in subsequent years. In the summer and early fall we made a few fyke net sets south of Great Lakes Harbor ("Great Lakes"). The bottom substrate at this site was similar to the mixed sand and rock found at south of Waukegan site. From 1990 to 1993, fyke net sampling was confined to Camp Logan, south of Waukegan and Glencoe (N Tower and S Tower) and bottom trawling was done at the site north of Waukegan.

Collection methods - adult perch

For the purpose of analysis, fish collections were defined by seasons which were biologically useful, as follows: spring (i.e., spawning season) = May through June, summer = July through August, fall = September through October. Adult yellow perch were collected during the fall of 1986, spring and fall of 1987 and the spring of 1988 using gill nets. Gill nets were 600' long, comprised of two 50' panels (1.5 and 1.75" by 0.25" stretch mesh) and five 100' panels (2, 2.25, 2.5, 2.75, and 3" by 0.25" stretch mesh). The first 25 fish from each mesh size (if there were that many) were sampled for subsequent age estimation. None of these fish were tagged as part of this study.

In 1988 and 1989 fish were collected using a 3' x 6' double ended, single throated fyke net with 0.75" bar mesh and a 100' lead. The net was treated with tar to retard biofouling and UV degradation. From 1989 to 1993 we used a 4' x 6' doubled ended fyke net with two throats, 0.75' bar mesh, and a 100' lead. This net was treated in the same manner as the 3'x6' nets. All fyke nets were set overnight unless weather prevented their recovery, in which case the nets would be recovered as soon as weather permitted.

In 1988, nets and trawls were deployed from a 17' Boston Whaler. In 1989 a 32' work boat (the Sculpin) was acquired specifically for this project and all of the consequent work was done off that boat. In the winter of 1990-1991 the Sculpin was modified to carry a hydraulic winch and trawl frame which improved the efficiency of the trawl gear and enabled fyke netting in depths greater than 10 meters.

Fyke nets were used to primarily sample at 3 to 10 meters in 1988 to 1990 and at 4 to 15 meters in 1991 to 1993. The bottom trawls were used to sample young-of-year perch at 2.5 to 8 meters depth, although adults were caught incidentally. Primary periods of sampling varied from year to year. In 1988, we sampled only during the month of August. In 1989, we sampled large numbers of fish during the third week of May, and smaller numbers in June and July. Sampling frequency and catches improved in August and September. Trawling occurred in August and September. In 1990, frequent fyke net sets were made from early May through early June. Because of boat problems, sampling was not resumed until August. In 1991, all sampling was concentrated in the spring, from early May until the first week of July. A few fish were tagged and released in late July and late September and in May and June of 1992 as part of an unrelated study.

Tagging and data collection

Fyke net pots were brought to the surface one at a time, and fish were either removed with dip nets or, if the catch was small, the entire pot was brought aboard and emptied into a 32 gallon cooler on deck. The cooler was filled with lake water and no more than approximately 200 perch were added. On hot days, or if the fish started to appear stressed, the water was periodically exchanged with fresh lake water using 5 gallon buckets. A subsample of 25 fish or ten percent of the estimated catch was removed with a small dip net for dissection and aging. Yellow perch over 150mm long and in good condition were tagged, measured, sexed and released. Sex was determined by the presence of gametes in ripe fish; spent females could often be identified by the presence of a cloacal protuberance and flaccid belly. Yellow perch were measured from the tip of the anterior of the head to the end of the compressed tail (maximum total length). Fish were marked using vinyl anchor tags (Floy tags) which were individually numbered and bore the address of the Lake Michigan Biological Station and the initials of the Illinois Natural History Survey. The tag was placed on the left side of the fish above the lateral line below the soft rays of the first dorsal fin (Figure 3). Recaptured yellow perch were measured, sexed, and released. Other species were counted and noted. Yellow perch under 150mm or in poor condition were measured, sexed and released. If the gas bladder was over-inflated because of pressure change or stress, the gas bladder was punctured with the hollow needle of the tagging gun to relieve the excess pressure. This procedure was usually necessary for fish caught deeper than 7 meters, especially if the fish were crowded in the pot.

Recapture Methods

Tagged fish were recaptured primarily with our own gear (fyke nets and trawls), and by commercial sources (commercial gill net fishermen, trap net fishermen and wholesale fish processing houses), anglers (both rod and reel and power line anglers), and state fisheries agencies (IDOC, WDNR). Whenever possible we obtained data on the recapture location, date and method of recapture, and the length of the fish.

Aging

All sub-samples of field-caught yellow perch were taken to the Lake Michigan Biological Station where they were measured, weighed, sexed, and otoliths were removed and stored in alcohol. Otoliths were prepared by removing them from alcohol and breaking them crosswise through the nucleus. The broken edge was held in the flame of an alcohol lamp for a short period to accentuate the rings. The otolith was then mounted, burned edge up, in a small piece of modeling clay. The burned surface was wet with immersion oil and viewed at 10 - 63X with fiber-optic illumination. Counts were made using the proximal-ventral field of the right sagitta. A set of four guidelines were used to assist the readers: 1) annuli are conspicuous in the posterior ventral field; 2) annuli are also apparent somewhere along the dorsal side of the otolith; 3) when spring-caught fish appear to have a full year's growth between the otolith margin and the last apparent annulus, the otolith margin is counted as an annulus; 4) spacing of the annuli is regular. The reader assumed that there were no instances where markedly low growth in one year was followed by markedly increased growth in the following year. When annuli seemed to reflect such a pattern, one or more was assumed to be a false annulus.

Abundance estimation

We used the abundance estimates of Lincoln (1930), Jolly (1965), and Seber (1965), outlined by Gulland (1969) and discussed at length by Southworth (1978). Calculations were performed using a Microsoft Excel worksheet on an IBM-compatible microcomputer. All data for this study were entered and analyzed using RBase ver. 3.2.

Juvenile abundance study

Yellow perch in their first year of life were sampled at three stages, which we designate as larvae, fry, and young-of-year. Larval perch are approximately 5 mm long when they hatch, and remain planktonic in the upper 1-1.2 m of water at night for the first three to four weeks of life (Becker 1983). By mid-July the oldest larvae are 25 mm long, and descend to the bottom of the lake where they remain for the rest of the year. The largest larvae caught in our larval sampling nets were 13 mm long, and the smallest young-of-year fish sampled in fall were 30 mm. The stage in between these two we termed "summer fry".

Larval perch sampling

Larval yellow perch were collected near Waukegan Harbor, IL, at two offshore transects two miles apart. Collections were made at night by pushing a 0.5m diameter 363μm mesh plankton net, held at a depth of 0.5 meters, at a speed of approximately three to four knots for a distance of 0.5nm. A calibrated General Oceanics™ standard flowmeter mounted in the mouth of the net was used to estimate the volume of lake water filtered. The fish were anesthetized in MS222 before transferring them to 95% ethanol in order to prevent regurgitation of stomach contents. Collections were made approximately weekly between mid-May and mid-July from 1988 to 1990; samples were taken on only 4 and 6 nights in 1991 and 1992, respectively, and collections were made approximately every four nights from mid-May to late July in 1993. On each collection night four 0.5m transects were sampled, two in 5m and two in 10m of water. Surface temperature was recorded at the location of each push. On a few dates, duplicate pushes were made of two or more of the transects.

Larval fish in each sample were identified using Auer (1982) and counted. Other organisms such as ostracods and *Bythotrephes cederstromii* were enumerated in many of the samples to provide data for other ongoing studies.

Summer fry sampling

Considerable effort was expended to collect juvenile perch in mid-summer. Bottom trawling with the 16' otter trawl was done off Waukegan, Wilmette, and north of Racine in Wisconsin wherever we could find soft substrates which would not snag the trawl. A 50' bag seine was deployed in 1.5 m of water north and south of Waukegan, at North Point, south of Milwaukee, and in Indiana. A 10 m purse seine was deployed in 5 m of water off Waukegan. A benthic sled with a 1000 µm plankton net attached was used south and north of Waukegan. We did midwater sampling south of Waukegan using a 1000 µm mesh plankton net with a 0.5 m opening, and using the 16' otter trawl modified with 1000 µm plankton mesh in the cod end. None of these techniques yielded any juvenile perch in mid-summer, so quantitative measures of effort have not been tabulated. Our inability to find yellow perch fry in late summer presents an interesting problem. Mid-summer fry 9-17mm long have been captured successfully in a small lake within three meters of the surface using both meter nets and Miller high-speed samplers, though avoidance was considerably reduced by adding an electroshocker to the mouth of a translucent Miller sampler (Noble 1970, 1971). Clearly, additional sampling with new or modified gear needs to be tried in order to find this elusive life stage.

Young-of year sampling

In August through October from 1987 to 1992, young-of-year perch were collected using 10' and 16' semi-balloon bottom trawls with 0.25" bar mesh in the cod end. The 10' trawl was used in 1988 and 1989, and the 16' trawl was used from 1989 on. The trawls were pulled at three knots for either five or ten minutes. Catches of YOY yellow perch were standardized to the number of YOY per 1000m^2 of bottom and yearly averages were taken. These trawls incidentally caught a significant number of adult fish in 1989.

RESULTS

Assessment of reliability and quality of tag return sources

The bulk of our recapture data comes from three major sources: state and federal agencies, including ourselves; sport fishermen, both shoreline and boat; and commercial fishermen using gill nets, trap nets and drop nets. Tagged fish from commercial fishermen are also reported by wholesale fish houses who receive the fish. The most reliable information comes from our data and those from other fisheries agencies assessing fish stocks in Lake Michigan. These fish are collected and measured by trained personnel whose purpose is to look for tags and collect data. Therefore, measurements are made carefully, maximum total length is consistently measured (rather than fork length or standard length), and a full description of the gear used, location, depth and the date is recorded.

Sport fishermen return many tags but the reliability of their data may not be high. Tags are often not returned due to indifference or lack of understanding of what the tag represents. Inaccurate reporting can be detected when, for example, the reported fish length is shorter than when the fish was tagged, or indicates an extremely high growth rate. Identification of the site and date of recapture is usually good, though a small percentage of tags are returned simply as a number on a piece of paper; occasionally the address is listed as the tag number by mistake. The

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Estimation of tag reporting by commercial fishermen in Illinois

Commercial fishermen process large numbers of fish very rapidly, so the probability that they will miss a tag may be quite high. The fact that tags are occasionally if not frequently missed is indicated by the return of over 100 tags from commercial fish processing houses which receive fish from the commercial fishermen.

Estimation of the tag reporting rate by commercial fishermen is problematic because their catch rates are not well known. At best, their catches are estimated from the number of pounds of fish they pull in (averaged at four to the pound); at worst, their catch rates may be mis-reported if they catch more than their permitted quota. Mis-reporting may also vary between fishermen. All commercial fishermen during the period of this study reported catching their quota. Our best estimate of the number of tagged fish reported by commercial fishermen was derived by using the fishermen who reported the highest proportion of tags in three out of four years as a baseline. This method is clearly inadequate, however, given the high variation in reporting rates which it produces (Table 2).

Table 2. Reporting rates of tagged fish by commercial fishermen in the Illinois waters of Lake Michigan estimated from recapture rates reported by commercial fisherman 'x'.

Year	Tagged perch reported by x	Total perch caught by x	Recapture rate by x	Reported perch harvest	# Tags returned by all fishermen	Expected tag returns	Reporting rate (%)
1989	7	220,000	0.00003	880,000	13	28	46
1990	22	220,000	0.0001	660,000	65	66	98
1991	25	220,000	0.0001	880,000	79	100	79
1992	5	220,000	0.00002	880,000	9	20	45

Distribution and movements of adult perch (Objective 2)

During the four years of this study, plus preliminary work in 1988, we caught 105,548 adult yellow perch in fyke nets and trawls (Table 3). Of these fish, 55,346 were tagged. As of the writing of this report we have collected data from 1,548 recaptured fish, representing 2.8% of the tagged fish (Table 4). Thirty-seven percent of the fish were recaptured by anglers, 35% by ourselves or other state agencies, and 27% by commercial fishermen.

Yellow perch were recaptured throughout the lake along both shorelines, from Bailey's Harbor on the west shore to Manistee on the north-east shore. However, the majority of recaptured fish were collected within a 25 mile radius of our primary collecting sites at Zion and Waukegan (Figures 4,5). High recapture rates were also seen in areas of high fishing pressure, i.e., Chicago, IL, Milwaukee, WI, and Michigan City, IN.

Perch were most abundant at our nearshore collecting sites in the spring, due to the inshore movement of ripe fish to spawning areas. Among the sites we sampled, we consistently captured the highest numbers of fish at the south Waukegan and Camp Logan sites each spring (Tables 3 and 4). Both sites appear to represent foci of spawning aggregations. Perch showed a tendency to return to the same site each spring for spawning. This site fidelity is most clearly illustrated by Figure 6, which shows that over 30% of fish tagged at Camp Logan in spring were recaptured at the same site in the same or successive spring seasons (see also Table 5). Similarly, 25% of fish caught at S. Waukegan returned to S. Waukegan in spring, and 30% of the fish tagged at Tower Rd. in spring returned to Tower Rd. in spring. Some wandering occurred between the Camp Logan and S. Waukegan sites (Figure 6). This may indicate that the spawning 'site' is in fact a broad stretch of shoreline several miles long, or that fish may return either to their former spawning site or to a site adjacent to the one used in a previous year.

After spring spawning, fish wandered widely in summer and fall (Figures 5 and 7, Table 5). The location of fish in summer and fall could not be predicted by the site at which they were tagged. Fish had a similar likelihood of being re-captured at all distances from 2 to 20 miles from the tagging site (Table 5). Of particular interest, however, is that a consistently high proportion of fish caught at S. Waukegan in summer and fall were recaptured at all seasons 20-40 miles away (Table 5). These fish tended to wander north of the tagging site, whereas fish tagged at Camp Logan and Tower Rd wandered both north and south in approximately equal frequencies (Figure 7). These data indicate that a sizable proportion of fish tagged in Waukegan are caught by anglers and commercial fishermen in Wisconsin.

Distribution and abundance of juvenile perch (Objective 3)
Information about abundance of larval perch over time were most complete in the two years in which intensive sampling took place: 1987 and 1988 (Figure 8, Table 6, Appendix I). Larval fish first appeared in low numbers in the nets in the first week of June, and mostly disappeared by the second week in July. The CPE varied considerably from year to year, with peak catches from 3,935 perch/m^3 in 1990 to 915/m^3 in 1992. (Table 5). The standard errors on these catch estimates are quite high, due to the high variability in number of fish caught among the four transect sites (Appendix I). The timing of peak abundance varied from June 13 in 1991 to June 25 in 1990. However, the data indicate that we likely missed the spawning peak in 1991 and 1992. Within the limitations of the data, there is a suggestion of a three-year cycle of abundance. CPE figures were high in 1987 and 1990, and decreased in the two years thereafter. The duration of peak abundance varied highly - in 1990 we detected one day of extremely high abundance, whereas in 1987, 1988, and 1992 the CPE data were similar for over a week. These figures suggest that larval abundance in our collections is highly influenced by extrinsic factors such as wind and water temperature. Consequently, larval abundance estimates are not dependable for predicting year class strength. Research on the factors which affect larval abundance in sampling collections may yield insights on larval survival and early establishment of year class strength.

Table 3. Summary of adult yellow perch collected and tagged in southwestern Lake Michigan, 1988-1991. Average lengths are given with the standard deviation. * indicates absence of data by sex. Totals which are greater than the sum of males plus females reflect the inclusion of fish which were not identified by sex. Com. = tag returns from commercial fishermen; agency = tag returns from our own collecting effort, and assessments by state agencies. All samples were collected using fyke nets unless otherwise noted.

Year	Season (gear)	Site	Total Caught	Average Length in millimeters: Male	Female	Total	Number Tagged: Male	Fem.	Total	Tags returned (all sources): Angler	Com.	Agency	Other	Total
1988	Summer	S Waukegan	92	*	*	190±29.2	*	*	90	2	3	0	0	5
		N. Chicago	175	*	*	187±13.1	*	*	165	4	1	0	0	5
1989	Spring (trawl)	S Zion Nuke	41	187±11	*	190±14.3	14	*	32	1	1	0	0	2
		N Waukegan	6	*	*	182±6.38	*	*	5	0	0	0	0	0
		S Waukegan	6,541	185±15.6	201±15.5	185±15.7	4,042	18	4,236	36	24	34	1	95
	Summer (trawl)	Camp Logan	656	*	*	186±20.9	*	*	540	3	6	1	0	10
		N Zion Nuke	38	*	*	180±16.6	*	*	17	0	0	0	0	0
		S Zion Nuke	9	*	*	206±6.99	*	*	5	0	0	0	0	0
		N Waukegan	698	182±0	*	178±19.6	1	*	513	9	5	1	0	15
		S Waukegan	2,942	183±25.1	*	191±24.2	15	*	2,592	26	37	2	1	66
		Great Lakes	200	*	*	194±33.1	*	*	184	2	3	0	0	5
		N Tower	137	*	*	194±32.9	*	*	129	2	2	1	0	5
	Fall (trawl)	Camp Logan	24	*	*	176±17.1	*	*	19	0	0	0	0	0
		N Waukegan	239	*	*	185±19.7	*	*	229	5	9	0	0	14
		S Waukegan	1,092	*	*	192±26.1	*	*	938	13	19	3	0	35
		Great Lakes	37	*	*	221±39.2	*	*	36	0	2	0	0	2
1990	Spring	Camp Logan	11,509	197±15.7	210±18.2	197±15.8	9,107	16	9,126	96	72	103	1	272
		S Waukegan	12,943	201±15.7	236±40.2	201±16.3	7,922	28	8,068	122	84	186	2	394
		N Tower	1,622	196±18.1	*	196±18.3	1,526	*	1,540	23	8	3	0	34
		S Tower	1,215	194±16.9	194±19.8	195±18.4	1,076	2	1,145	33	21	12	0	66
	Summer (trawl)	N Waukegan	14	*	*	166±15	*	*	7	0	0	0	0	0
		S Waukegan	477	*	*	203±40.3	*	*	365	4	3	0	0	7
	Fall	N Waukegan	348	*	*	188±21.6	*	*	296	0	3	1	0	4
		S Waukegan	5,146	*	*	190±26.3	*	*	4,321	25	26	6	1	58

Table 3. Continued.

Year	Season (gear)	Site	Total Caught	Average Length in millimeters: Male	Female	Total	Number Tagged: Male	Fem.	Total	Tags returned (all sources): Angler	Com.	Agency	Other	Total
1991	Spring	Camp Logan	10,021	197±18.7	208±27.2	197±19.2	7,231	65	7,844	73	38	85	0	196
		S Waukegan	13,962	197±19.7	217±42.3	195±21.1	6,439	55	7,851	61	34	21	0	116
		N Tower	7,714	195±21.4	272±43.5	196±24.4	3,207	14	3,951	33	11	85	0	129
	Summer	Camp Logan	168	191±17.8	*	192±19.4	5	*	19	3	0	0	0	3
		S Waukegan	223	*	*	200±31.6	*	*	207	1	2	0	0	3
	Fall	Camp Logan	785	*	*	202±22.5	*	*	496	4	2	0	0	6
1992	Spring	Camp Logan	19,479	202±17.9	*	202±17.89	315	1	323	0	1	0	0	1
		S Waukegan	6,362	*	*	*	*	*	0	*	*	*	*	*
		N Tower	246	*	*	*	*	*	0	*	*	*	*	*
	Summer	Camp Logan	108	*	*	203±23.13	*	*	57	0	0	0	0	0
		S Waukegan	184	*	*	*	*	*	0	*	*	*	*	*
		N Tower	95	*	*	*	*	*	0	*	*	*	*	*

Table 4. Summary of recaptured fish by site, season, sex, year, and source of tag return. Seasons were defined as follows: spring = May through June, summer = July through August, fall = September through October.

Year	Season	Site	Total Caught	Number Tagged: Male	Female	Total	Tags returned (all sources): Angler	Com.	Agency	Other	Total
By season											
	Spring	Camp Logan	41,009	16,653	82	17,293	169	111	188	1	468
		S Zion Nuke	41	14	*	32	1	1	0	0	2
		N Waukegan	6	*	*	5	0	0	0	0	0
		S Waukegan	39,808	18,313	101	20,155	219	142	241	3	605
		N Tower	9,582	4,733	14	5,491	56	19	88	0	163
		S Tower	1,215	1,076	2	1,145	33	21	12	0	66
	Summer	Camp Logan	932	39	*	616	3	6	1	0	10
		N Zion Nuke	38	*	*	17	0	0	0	0	0
		S Zion Nuke	9	*	*	5	0	0	0	0	0
		N Waukegan	712	*	*	520	9	8	2	0	19
		S Waukegan	4,093	15	*	3,254	31	42	2	1	76
		Great Lakes	200	*	*	184	2	3	1	0	6
		N Tower	232	*	*	129	2	2	1	0	5
	Fall	Camp Logan	809	*	*	515	0	0	0	0	0
		S Waukegan	6,238	*	*	5,259	38	45	9	1	93
		N Waukegan	587	*	*	525	5	12	2	0	19
By year											
	1988		267	*	*	255	6	4	0	0	10
	1989		12,660	4,072	18	9,475	97	108	42	2	249
	1990		33,274	19,631	46	24,868	303	217	311	4	835
	1991		32,873	16,882	134	20,368	175	87	191	0	453
	1992		26,474	315	1	380	0	1	0	0	1
Grand Total			105,548	40,900	199	55,346	581	417	544	6	1,548
% recaptures							1.05	0.75	0.98	0.01	2.80

Table 5. Percentage of fish tagged in a given season recaptured in each successive season, summarized by distance of recapture from tagging site. Data are summarized for all years of the study.

Season Tagged	Total Tagged	Season of recapture		Distance between tagging and recapture sites (miles) 0-1	2-5	6-10	11-20	21-40	41-60	61-80	81+
All sites											
Spring	1308	Spring	5/1-6/30	36	4	8	4	3	1	1	0
		Summer	7/1-8/31	0	3	4	4	4	1	1	1
		Fall	9/1-10/31	0	1	1	3	4	0	0	0
		Winter	11/1-4/30	0	0	0	4	7	1	2	0
Summer	123	Spring	5/1-6/30	2	4	2	5	12	1	2	0
		Summer	7/1-8/31	2	8	2	2	8	2	0	2
		Fall	9/1-10/31	2	2	2	2	10	0	0	1
		Winter	11/1-4/30	1	2	1	1	13	1	7	2
Fall	126	Spring	5/1-6/30	3	4	5	4	12	2	2	0
		Summer	7/1-8/31	2	5	4	2	6	2	1	1
		Fall	9/1-10/31	2	3	2	1	7	2	0	1
		Winter	11/1-4/30	0	0	2	1	23	3	0	1
S. Waukegan only											
Spring	606	Spring	5/1-6/30	35	5	7	4	4	0	0	0
		Summer	7/1-8/31	1	4	2	3	5	2	1	2
		Fall	9/1-10/31	0	2	0	1	6	0	0	0
		Winter	11/1-4/30	0	0	0	1	11	1	1	0
Summer	81	Spring	5/1-6/30	1	4	1	5	14	1	1	0
		Summer	7/1-8/31	1	10	2	1	7	2	0	2
		Fall	9/1-10/31	4	1	2	1	11	0	0	1
		Winter	11/1-4/30	0	2	0	0	14	1	7	0
Fall	103	Spring	5/1-6/30	4	9	3	3	13	1	2	0
		Summer	7/1-8/31	1	6	4	3	6	2	1	1
		Fall	9/1-10/31	3	3	2	1	6	2	0	1
		Winter	11/1-4/30	0	0	1	0	20	3	0	1
Camp Logan only											
Spring	472	Spring	5/1-6/30	35	2	11	4	3	0	1	0
		Summer	7/1-8/31	0	3	6	4	3	1	1	1
		Fall	9/1-10/31	0	0	1	5	3	0	1	0
		Winter	11/1-4/30	0	0	0	8	4	0	3	0
Tower Rd. sites only											
Spring	232	Spring	5/1-6/30	42	5	7	6	3	3	0	0
		Summer	7/1-8/31	1	0	3	6	3	0	0	0
		Fall	9/1-10/31	0	0	1	2	2	0	0	0
		Winter	11/1-4/30	0	0	1	6	2	4	0	1

Table 6. CPE of larval yellow perch collected off Waukegan, Lake Michigan, 1987-1992, averaged over all four sampling transects per night. CPE is expressed in number of perch per 1000 m^3.

1987

Date	Mean	SD
5/21/87	0	0
5/22/87	0	0
5/26/87	2	6
5/27/87	0	0
5/29/87	0	0
5/30/87	4	10
6/2/87	5	10
6/3/87	3	6
6/4/87	47	79
6/6/87	0	0
6/8/87	0	0
6/9/87	36	36
6/10/87	218	350
6/12/87	193	103
6/16/87	3,890	8,543
6/19/87	413	620
6/23/87	2,324	4,396
6/26/87	3,174	7,087
6/30/87	128	208
7/3/87	2	3
7/9/87	0	0

1988

Date	Mean	SD
5/18/88	0	0
5/20/88	0	0
5/25/88	2	3
5/27/88	0	0
5/29/88	2	3
5/31/88	0	0
6/4/88	19	24
6/6/88	28	35
6/11/88	876	1,553
6/12/88	336	614
6/14/88	266	374
6/16/88	2,040	3,571
6/18/88	303	326
6/20/88	142	161
6/23/88	1,838	1,616
6/25/88	1,095	1,298
6/27/88	550	293
7/1/88	892	768
7/3/88	78	123
7/5/88	41	39
7/7/88	7	5
7/9/88	9	7

1989

Date	Mean	SD
6/3/89	21	23
6/6/89	108	172
6/13/89	982	1,303
6/20/89	674	738
6/26/89	511	993
7/3/89	24	27
7/10/89	2	3
7/17/89	0	0

1990

Date	Mean	SD
5/30/90	0	0
6/5/90	51	33
6/11/90	119	115
6/21/90	0	0
6/25/90	3,935	7,403
7/2/90	903	1,310
7/9/90	33	0
7/16/90	2	3
7/23/90	0	0
7/31/90	2	3

1991

Date	Mean	SD
6/13/91	1,205	1,070
6/17/91	164	187
6/24/91	146	43
7/2/91	8	7

1992

Date	Mean	SD
6/22/92	879	870
6/25/92	721	751
6/30/92	915	906
7/6/92	124	233
7/9/92	19	33
7/15/92	0	0

Young-of-year perch densities varied greatly over the 6 years of sampling (Appendix II, Figure 11). The highest densities were caught in 1987 and 1988 (53.36/1000m^2 and 90.58/1000m^2 respectively). Density declined sharply in 1989 to 5.90/1000m^2 and even further in 1990 to 0.66/1000m^2. No young-of-year yellow perch were found in either 1991 or 1992. A comparison between the relative densities of young-of-year perch and the relative year class strength from the 1992 fyke net samples between 1987 and 1992 indicates that the young-of-year densities estimated from trawling are good indicators of relative year class strength. The densities in 1987-1989 correspond well with the relative year class strength in the 1992 samples (Figure 11).

Age and growth (Objective 1)

In the four years of this study, plus three years of related studies, 3580 yellow perch were aged using otoliths (Table 7). Of these, 2658 (74%) were males and 678 (19%) were female; the rest were not identified by sex. The age distribution of both sexes was similar, although in some years very few females were aged (Table 8). Females were, on average, larger than males in all samples. Size dimorphism is characteristic in yellow perch (Scott and Crossman 1973), though Wells and Jorgenson (1983) noted that the difference between males and females was lower in Illinois and Indiana waters than in Michigan waters. Fish in the 1983 and 1984 year classes were small compared to fish in the 1986-1988 year classes (Figure 9). This phenomenon is not necessarily related to year class strength because the 1983 and 1984 years classes had similar growth rates but 1983 was a much stronger year class than 1984.

Table 7. Summary of fish used for age and growth.

Year	Season	Collection Method	Males	Females	Unknown	M/F	Total
1986	fall	gill net	175	141	0	1.24	316
1987	spring	gill net	176	31	0	5.68	207
	fall	gill net	118	102	0	1.16	220
	total						427
1988	spring	gill net	579	224	0	2.58	803
1989	summer	fyke net	145	60	0	2.42	205
	fall	fyke net	41	18	0	2.28	59
	total						264
1990	spring	fyke net	548	2	0	274.00	550
	summer	fyke net	0	0	54	0.00	54
	fall	fyke net	1	0	190	0.00	191
	total						795
1991	spring	fyke net	565	73	0	7.74	638
	summer	fyke net	6	4	0	1.50	10
	total						648
1992	spring	fyke net	284	14	0	20.29	298
	summer	fyke net	20	9	0	2.22	29
	total						327
Total			2658	678	244		3580

Table 8. Age distribution of yellow perch summarized by sex and year of capture.

Year caught	Sex	N	Age 1	2	3	4	5	6	7	8	9	10	11	12	13
1986	Male	165			48	47	1	68	1						
	Female	151		2	77	60	1	11							
1987	Male	289		4	14	128	73	2	61	6	1				
	Female	138		2	8	96	28		4						
1988	Male	579		1	50	42	299	122	6	59					
	Female	225		2	20	47	135	19		2					
1989	Male	187	2	32	32	21	14	59	12		14	1			
	Female	77	3	40	18	7	4	5							
1990	Male	549			24	82	89	73	192	60	12	16	1		
	Female	2			2										
1991	Male	569		2	75	71	98	60	34	163	44	6	16		
	Female	77		3	51	16	3	1		2	1				
1992	Male	304			6	61	48	48	35	19	56	19	6	5	1
	Female	23			1	5	9	2	1	1	1	2			1

Sex ratio

Yellow perch could only be reliably sexed in the field during spring, when they were ripe, or in the laboratory by dissection. The sex ratio of fish sampled was always skewed toward higher numbers of males, although the ratio of males to females varied with the season. In summer and fall the sex ratio ranged from 1.2 to 2.6 (Table 7), whereas in spring the ratio was much higher: 2.6 - 274 in subsampled fish, and 111 - 569 in field-sexed fish (Tables 3 and 7). The sex ratio of spring-caught fish reflects the spawning behavior of yellow perch (Scott and Crossman 1973, Bruch et al. 1985). Males move into shallow water early in spring and remain there throughout the season, while females come inshore only to spawn, and then depart. It is not clear why the sex ratio is not 1:1 in summer and fall, or whether this is just a local phenomenon in Illinois waters. Wells and Jorgenson (1983) observed a 1:1 ratio of males and females in summer in Michigan waters, but a 3:1 ratio in Illinois and Indiana. Sex ratios which are skewed in favor of females can be indicative of a stressed population (Bowen et al. 1991); why the yellow perch sex ratio is skewed in favor of males is unclear.

Year class strength (Objective 1)

The number of year classes of yellow perch present in the population appears to have increased over the past seven years (Figure 10a-h). The 1986-1988 samples contained only 6-8 year classes of fish, whereas eight to eleven year classes of yellow perch were represented in the fyke net collections in later years (Table 7, Figure 10d-h). The population of yellow perch was therefore composed of up to 13 year classes, given that the fyke nets do not sample fish until they are 2 to 3 years old. Thirteen year old fish were seen in 1990 (1977 year class) and in 1992 (1979 year class). Fish older than 11 years were usually absent or in low abundance; over 90% of the fish in each year were between the ages of 3 and 9. Either the 1974-1976 year classes were not as strong as in subsequent years, and/or adult mortality was much higher during the late 1970's and early 1980's than recently. Depensatory mortality due to higher predation on small year classes could have occurred.

The yellow perch in Lake Michigan became vulnerable to our fyke nets late in their second year of life and were assumed to be fully recruited during their third year. For example, the 1987 year class was very strong in samples taken in the fall of 1989 (Figure 10d), and the 1988 year class was abundant in the 1990 fall samples (Figure 10f). The 1988 year class is absent, however, in the spring 1990 samples (Figure 10e). The 1987 and 1988 year classes never returned to the levels of relative abundance seen in the fall of their second year. It appears that fall fyke nets sample a disproportionately high number of two year old fish.

The most striking aspect of the age distributions of fish collected each year is the consistent presence of two strong year classes, spawned in 1983 and 1988 (Figure 10a-h). The most recent data, from 1992, summarize the year class abundance over the past 14 years and suggests the presence of a four to five-year cycle of year class strength (Figure 11). Weak year classes in 1979 and 1984 were followed by progressively stronger year classes, culminating in a peak four years later (1983 and 1988). The 1980 year class appears to represent the peak of a previous cycle, barely detected in our early samples in 1986-1988 (Figures 10a-c); however, this was a relatively weak 'peak year'. If these cycles are consistent, we would expect the next strong year class to appear in 1993, preceded by successively stronger year classes in 1990, 1991, and 1992. In fact, this has not occurred. The 1990 year class of adults was absent in the 1992 sample (Figure 11). Young-of-year densities in 1990 were lower than in 1989 and no young-of-year yellow perch were found in 1991 and 1992 (Figure 11, Appendix 2).

Survival and Abundance estimates (Objective 1)

Mortality and abundance estimates from tagged fish are affected by several sources of error, which can be summarized as (1) poor estimates of catch efforts, (2) incomplete reporting of tag returns, (3) unequal vulnerability of tagged and untagged fish to capture techniques, (4) tag loss, (5) increased mortality of tagged fish, (6) unequal mixing of tagged and untagged fish, and (7) emigration of tagged fish (see Gulland 1969, Southworth 1978). Each of these sources of error will be discussed in relation to this project.

(1) and (2): Estimates of catch and reporting of tag returns were discussed earlier. We clearly cannot use the commercial fishing tag returns for abundance estimation; we also cannot use data from state assessments because we do not have their catch estimates. The most complete and reliable data are those from our own work at the sites where we did the most intensive sampling and collected the most tagged fish, i.e., S. Waukegan and Camp Logan.

(3): We have no reason to suppose that tagged fish were either more or less vulnerable to the capture gear than untagged fish. Floy tags, unlike Petersen disks or button tags, do not tend to foul in fishing gear, and fyke nets are less likely to catch a tag than gill nets. We never encountered a tangled tagged fish in our fyke nets.

(4), (5) and (6): Tag loss and mortality due to tagging were estimated, in part, by an experiment to examine the effect of puncturing the gas bladder on survival of deep-caught fish. Results of this work will be reported elsewhere (M. J. Keniry, WDNR, in prep.). The data indicate that puncturing greatly increases the survival of yellow perch caught below 10m. Tagged, punctured fish brought back to the hatchery suffered 1% mortality in the first four days; no tag loss was observed in the hatchery, and no segregation of tagged and untagged fish was apparent (error source 6). Tag loss is likely to have occurred in the field, however. When tagging fish for the mark and recapture study, scars at the tagging site were observed on two occasion in 1991. During the same period we observed 240 recaptures, giving us an estimated long term tag loss rate of 0.8%. Unfortunately we feel that this number is too low as tag loss was probably higher when the tagging crews were inexperienced in 1989. Muoneke (1992), using experienced crews in a double tag study (using the same model tag that we used) during two years in Lake Whitney, Texas, estimated a long term annual shedding rate for white bass at 25%. He also noted that some of the fish exhibited sores around the tag site caused by the tag stem which could lead to tag loss or increased chance of mortality due to infection. These same sores have been observed on our tagged yellow perch. Even fish with tag sores appeared to be otherwise in good condition, which suggests that long-term mortality due to tagging is minimal. Both Muoneke (1992) and Franzin and McFarlane (1987) noted the presence of filamentous algae build-up on the tags which could increase the chance of the tag snagging on objects and being torn loose. In the absence of data to quantify these factors, we will use an estimated tag loss rate of 10%.

(7): The remaining source of error is the most problematic: emigration of fish outside the capture area. As many as 45% of the fish tagged at a given site in Illinois were caught outside the state. As noted above, however, fish tended to remain in or return to the same location in spring. To minimize all potential sources of error, therefore, our most reliable set of data to use for abundance estimation are our own spring tagging and recapture data from Camp Logan and S. Waukegan. These data include 36,545 tagged fish, or 66% of the total tagging effort.

Lincoln Index

The simple index of Lincoln estimates total population size as $(an)/r$, where a = the total number of marked fish, n = the recapture sample size, and r = the number of recaptured fish. The variance on this estimate is given as

$$\text{var } N = \frac{a^2 n(n-r)}{r^3} \qquad \text{(from Southwood 1978)}$$

If we apply this equation to the spring capture and recapture data from S Waukegan, we obtain the following estimates of the population size (N) of age 2+ yellow perch off Waukegan in spring:

Table 9a. Population abundance estimates using the Lincoln index (Southwood 1978)

Year	Population size (N)	Variance
1989	13,853,838	9.59 E+13
1990	1,033,902	1.05 E+10
1991	18,269,277	5.56 E+13

While the estimates could be realistic, their variability among the three years is very large and the variances are absurd. Clearly, a more robust estimator is needed. A much better estimator is the stochastic method developed by Jolly and Seber (see Southwood 1978). Even though this is currently one of the most-widely used models for estimating population size, it is not highly reliable when less than 9% of the population is sampled and when the survival rate is less than 50%. The first criteria is clearly a problem for this study, in which we are sampling an exceedingly small area enclosing part of a semi-panmictic (lake-wide) population. The estimates using the Jolly-Seber method are given below. While the population sizes are similar to those estimated using the Lincoln index, the variances again suggest that these figures have little value.

Table 9b. Population abundance estimates using the Jolly-Seber method (Southwood 1978)

	Proportion of recaptures $\alpha_i=r_i/n_i$	# of marked animals at risk $M_i=(a_iZ_i)/R_i+r_i$	Total population $N_i=M_i/\alpha_i$	Survival rate $\phi_i=M_{i+1}/(M_i-r_i+a_i)$	Variance*[1]
1990	7.7E-05	1,658	21,457,183	3.95E+00	4.83862E+14
1991	0.00688	38,370	5,580,382	1.93E+00	4.98552E+12
1992	0.00519	89,101	17,177,593		3.36921E+14

Table 9c. Survival (-Z) of yellow perch in three years in Lake Michigan, estimated using Gulland (1969).

	Year Class						
Year	1982	1983	1984	1985	1986	1987	1988
1990	0.66	0.42	0.31	0.38	0.65	1.56	1.56
1991	0.95	0.55	1.01	0.72	0.45	0.31	0.24
1992	0.46	0.72	0.42	0.42	0.50	0.38	0.47

Relative changes in abundance of adult yellow perch can also be compared using catch per effort data. However, these comparisons can only be made using data from the same gear type during the same sampling season. Data from the most consistently used gear, the 4x6 double-ended fyke net, are inconsistent among sites, in large part due

[1] Jolly's estimate, equation 3.36 in Southwood (1978), p. 110

to the high variance of the CPE estimates (Table 10). At Camp Logan the catches increased from 1989 to 1992, with a decline in 1991; at S. Waukegan the catches increased steadily over the same period, and at the N Tower site the catches decreased from 1990 to 1992. The data from the N Tower site are the least dependable, however, as this site was sampled on the fewest dates. The increase seen at the primary sampling sites, Camp Logan and S. Waukegan, is probably due to a great extent to the recruitment of the 1988 year class to the gear, starting in 1990.

Table 10. Catches per unit effort of adult yellow perch in Lake Michigan in each year of the study, summarized by season, gear type, and sampling site.

Sampling Site	Gear type	1989 mean	*SD*	1990 mean	*SD*	1991 mean	*SD*	1992 mean	*SD*
Spring									
Camp Logan	3x6 fyke	3.67	*1.71*						
S. Waukegan	3x6 fyke	0.87	*0.00*						
Great Lakes	3x6 fyke	2.73	*0.25*						
S Tower	3x6 fyke	0.17	*0.06*						
Camp Logan	4x6 fyke	4.44	*6.13*	50.74	*40.39*	21.34	*23.08*	100.60	*68.53*
Zion Nuke	4x6 fyke	2.28	*0.00*	6.67	*0.00*				
S. Waukegan	4x6 fyke	4.47	*4.68*	25.82	*25.98*	38.56	*41.20*	75.55	*68.40*
Great Lakes	4x6 fyke	0.67	*0.33*						
N Tower	4x6 fyke			64.37	*0.00*	48.14	*64.43*	5.61	*1.35*
S Tower	4x6 fyke	0.95	*0.86*	18.57	*12.58*				
Zion Nuke	trawl			6.67	*0.00*				
N Waukegan	trawl	588.91	*785.08*						
All sites	3x6 fyke	2.27	*1.71*						
	4x6 fyke	3.95	*4.61*	33.02	*32.01*	33.48	*41.05*	79.87	*71.13*
	trawl	588.91	*785.08*	6.67	*0.00*				
	all gear	83.01	*342.22*	57.38	*216.69*	33.48	*41.05*	79.87	*71.13*

Sampling Site	Gear type	1988 mean	*SD*	1989 mean	*SD*	1990 mean	*SD*	1991 mean	*SD*	1992 mean	*SD*
Fall											
S. Waukegan	3x6 fyke	2.55	*3.03*								
Camp Logan	4x6 fyke							6.71	*7.31*	2.28	*0.49*
S. Waukegan	4x6 fyke			54.21	*27.81*	5.46	*7.70*	4.55	*0.62*		
Zion Nuke	trawl			164.00	*0.00*						
N Waukegan	trawl			18.75	*6.25*	343.22	*531.50*				
All sites	3x6 fyke	2.55	*3.03*								
	4x6 fyke			54.21	*27.81*	5.46	*7.70*	7.05	*6.41*	2.28	*0.49*
	trawl			201.50	*68.66*	343.22	*531.50*				
	all gear	2.55	*3.03*					7.05	*6.41*	2.28	*0.49*

DISCUSSION

Distribution and movements of adult yellow perch (Objective 2)

Our tagging data indicate that a fairly strong spawning site fidelity exists in yellow perch in the Illinois waters of Lake Michigan. Spawning populations may therefore be relatively isolated from each other. Depending upon the extent of this isolation (in other words, the degree of wandering between spawning sites), genetically differentiated stocks may exist. Insofar as these stocks supply the fishable population of adult fish for each state, it is important to understand (1) whether such stocks exist, and (2) they extent to which stocks which spawn in one state are vulnerable to the fishery in other states. Tagging and movement studies of yellow perch in other lakes suggest that yellow perch may form discrete stocks (e.g. Mansueti 1960, Nakashima and Leggett 1975, Kelso and Ward 1977). Studies of yellow perch and the closely related Eurasian yellow perch (*P. fluviatilis*) indicate that these fish may home to the same general area to spawn each year (Clady 1977, Kipling and LeCren 1984). Fish that we tagged in spring tended to return to the same site in successive spring seasons; however, they wandered widely in summer and fall.

Tagging studies performed in 1981-1985 by the WDNR, primarily off Milwaukee, showed that the majority (79%) of the fish were recaptured within 10 miles of their tagging site in Milwaukee. Similar studies by the Indiana Department of Natural Resources (IDNR) off Michigan City showed that the Indiana fish wandered further; only 40% were recaptured within 10 miles of Michigan City. The IDNR noted that their fish were more likely to be recaptured to the west, rather than the east, of the tagging site, i.e., toward Illinois and western Indiana. Our tagged fish from S. Waukegan showed a similar tendency to wander north toward Wisconsin after tagging (Table 5). Clearly, fish spawning in Illinois are vulnerable to the Wisconsin fishery.

The stock structure of yellow perch in Lake Michigan fish is an important area for future research. If multiple stocks exist in Lake Michigan, then management actions in one state or management subunit could have a disproportionate effect on other areas. For example, management regulations that permit heavy fishing during the spawning season in one state could result in depletion of stocks that spend the remainder of the year in another state. For truly effective management, it is important to determine the stock structure of Lake Michigan yellow perch populations.

Age and growth (Objective 1)

On average, the yellow perch collected during this study were markedly smaller than perch caught in Illinois waters at similar seasons in the 1970's. Our summer-caught fish averaged 188.5 mm in 1988, 189.9 mm in 1989, 184.5 mm in 1990, 196 mm in 1991, and 203 mm in 1992. Wells and Jorgenson (1983), fishing between Waukegan and Michigan City in July and August of 1971-79, collected fish which averaged 212 mm (males) and 222 mm (females). All year classes of male perch we collected were smaller than fish measured by Schaefer

(1977) just north of Milwaukee in 1974 and 1975. In Table 11 we compare our data for average length of males in each year class with those from previous studies in south-western Lake Michigan. Caution must be used when comparing data among these studies, as the fish were collected using different gear (gill nets in all studies except ours), different methods were used for aging (other studies used scales, which are less reliable than the otolith method used in this study), the studies encompassed varying periods of time, and data from Schaefer (1977) and Wells and Jorgeson (1983) represented calculated lengths for the end of each year of life. With these caveats in mind, the data in Table 11 support the statement above that male perch collected in the 1980's were smaller than those collected in the 1970's. If we account for the difference between calculated year-end lengths and lengths averaged over the year by assuming our fish were the same size they would have been at the end of the previous year, the fish we collected would still be smaller than those from other studies, except at the end of their second year. McComish (1977, 1981, data tabulated by Wells and Jorgenson 1983) noted a steady decrease in the size of male perch collected off Michigan City in 1975, 1976, and 1979. (Note: data presented by Wells and Jorgenson make it clear that average fish lengths and weights vary considerably from site to site within Lake Michigan, so comparisons of data from different sampling sites is not useful). We did, however, observe an increase in the average length of our fish during the course of the study (Figure 9).

The decrease in average fish length indicates that fish grew more slowly in the 1980's than in the 1970's. This is likely due in part to the increased total population size, which may result in increased inter-specific competition for food. Growth of fish is usually higher in years of low population abundance, and fish reach larger sizes at a given age. Consequently, the lower average lengths we noted in males are probably a consequence of the relatively larger population size during the 1980's versus the 1970's.

Table 11. Length at age of male yellow perch (in millimeters) collected off Milwaukee and/or Waukegan in four separate studies. Note: lengths of spring fish are approximately equivalent to those of fish caught in fall the previous year (one year class younger).

Year(s)		Number of	Age						
of study	Season	fish used	1	2	3	4	5	6	reference
1971-1979	end-of-year	261	79	146	189	213	221	237	Wells & Jorgenson (1983)
1974-75	end-of-year	142	72	135	172	198	222	236	Schaeffer 1977
1985	spring	356	74	143	160	175	195	225	Bruch et al. 1985
1986	fall	163			170	186		205	this study
1987	fall	84			158	176	189		this study
1989	fall	25			174	180	188	190	this study
1991	spring	292			162	183	194	201	this study
1992	spring	148				180	192	200	this study

Year class strength (Objective 1)

Large fluctuations in year class strength are common in populations of yellow perch and the closely related European yellow perch (*P. fluviatilis*) (e.g., Forney 1971 and references therein). Year class strength is determined by the number of eggs spawned and survival of the fry. Egg production is related to adult abundance and health, whereas subsequent survival can be influenced by food abundance, cannibalism by adult perch (Alm 1952), predation (Forney 1971), temperature, and other climatic factors (LeCren 1965). Forney (1971) argued that year class strength of yellow perch in Oneida Lake was a product of depensatory mortality caused by higher predation on smaller year classes. Clady (1976) found that wind and temperature influence the survival of eggs and early fry, although the effect was not sufficient to explain the majority of variation in early mortality. Most studies, such as these, which have been able to demonstrate the influence of particular factors on year class strength, have been conducted in small inland lakes (also LeCren 1955, 1965, Clady 1977). The size of these lakes permits reliable estimation of total, rather than local, abundance of perch, their predators, and their prey species (e.g., Mills et al. 1987, Noble 1972).

Although our data clearly indicate the appearance of regular, periodic changes in year class strength, it is not clear what factors caused these fluctuations. The few data we have on young-of-year abundance show a clear correlation with year class strength in subsequent years, indicating that year class strength has been established by the end of the first year and is subsequently maintained (Figure 11). This observation suggests that young-of-year catches could be used as an indicator of year class strength and therefore abundance of yellow perch in future years; however, this assertion is tenuous without more supporting data.

Our observation of strong year classes in 1980 and 1983 reflects a similar finding by the Wisconsin Department of Natural Resources, who sampled perch in the Milwaukee outer harbor in 1982-1985 (Bruch et al. 1985). Their creel survey in 1983 and 1984 indicated that the 1980 year class was sustaining the fishery; they predicted that the 1983 year class would begin to bolster the fishery as of 1986.

Abundance estimates (Objective 1)

The tag-and-recapture data from this study can be used, at best, to estimate the size of the spring spawning populations at the two focal sampling sites, Camp Logan and S. Waukegan. The abundance estimates calculated using data from S Waukegan suggest that the local spawning population is in the order of magnitude of 5-20 million fish. However, the variances on these numbers indicate that little value can be placed on them. Basically, this type of study is limited by the size of the system (Lake Michigan) and the extent to which yellow perch do not form isolated populations even during the spawning season. The best that can be achieved with these data, therefore, is to compare the catch per unit effort data to estimate relative population abundance from year to year.

MANAGEMENT RECOMMENDATIONS

- The movements of yellow perch determined by our mark-and-recapture study suggest that yellow perch return to the same broad area to spawn each year. Fish which were recaptured at a site in spring other than where they were tagged in a previous spring may not have been spawning, or may have been caught en route to their original spawning site. If spawning site fidelity is high, it can lead to reproductive isolation and genetic differentiation of stocks. Knowledge of the extent of stock differentiation and lakewide perch stock structure is particularly important for perch management, given that perch which spawn in Illinois in spring tend to wander into different fishing jurisdictions during the summer and fall. We highly recommend that the stock structure of perch be examined using genetic techniques with high resolution, such as mitochondrial DNA and nuclear DNA analysis.

- This study provides distribution and movement data for yellow perch in Illinois waters of Lake Michigan. Similar data have been collected in recent years by the Wisconsin and Indiana Departments of Natural Resources. A collaborative effort among the states to combine these databases would greatly increase our understanding of broad yellow perch movements and relative seasonal abundance. This collaboration must initially focus on establishing a compatible database for all of the relevant studies.

- Yellow perch year class strength varies considerably, with cycles apparently occurring every four to five years. Strong year classes support the fishery through years of poor perch production. So long as the cycles of year class abundance are fairly short (3-5 years), the fishery can be maintained at a fairly constant level. Our data indicate the presence of at least three regular cycles, but the production of the next strong year class is uncertain. Age and growth data should be continued to track these cycles and ensure that strong year classes are available to support the fishery. Young-of-year perch should be monitored to determine whether their abundance can be used reliably to predict year class strength.

- Coordination of data among the four Lake Michigan states would greatly strengthen predictions of perch abundance. For example, absence of young-of-year perch in our surveys alone could have been due to local environmental conditions, such as persistent upwellings. Supporting data from Wisconsin and the USF&WS confirmed that the absence of these fish was a lakewide phenomenon, and therefore of general concern. Implementation of a yellow perch task group under the Lake Michigan Technical Committee is recommended as a vehicle for collaboration and rapid exchange of ideas and data.

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APPENDIX I

Larval yellow perch sampled near Waukegan, IL using a plankton net pushed just below the surface for 0.5nm.

		Sample Location / Depth										Total	
Year	Date	3/5	3/10	4/5	4/10	5	6	7	8	9	10	perch	SD
1987	21-May	0	0	0	0	0						0	
	22-May	0	0	0	0	0	0	0	0			0	
	26-May	0	0	0	0	1	0	0	0			0	
	27-May	0	0	0	0							0	
	29-May	0	0	0	0	0	0	0	0			0	
	30-May	0	0	0	0	0	4	0	0	1	0	0	
	2-Jun	4	0	0	0	1	0	1				4	
	3-Jun	0	0	0	0	0	0	1	2			0	
	4-Jun	0	0	1	0	2	11	38	10			1	
	6-Jun	0	0	0	0	0						0	
	8-Jun	0										0	
	9-Jun		4									4	
	10-Jun	2	5	185	19	3	38	35	33	0	5	211	
	12-Jun		2	32	19	29	42	44	8			53	
	16-Jun	30	157	4465	622	74	93	53	14			5674	
	19-Jun	1	8	14	20	130	328	51	26			43	
	23-Jun	0	7	744	2059	6	1	64	157			2810	
	26-Jun	23	312	0	4	293	3196	92	75			333	
	30-Jun	1	21	1	2	21	62	0	0			108	
	3-Jul	0	0	0	0	0	1	1	0			2	
	9-Jul	0										0	
1988	18-May	0	0	0	0							0	0.00
	20-May		0	0	0							0	0.00
	25-May	0	1	0	0							1	0.50
	27-May	0	0	0	0							0	0.00
	29-May	0	0	0	1							1	0.50
	31-May	0	0	0	0							0	0.00
	4-Jun	0	0	5	6							11	3.20
	6-Jun	0	2	3	12							17	5.32
	11-Jun	4	37	0	433							474	210.32
	12-Jun	1	4	7	167							179	81.54
	14-Jun	6	12	13	85							116	37.46
	14-Jun	3	4	33	158							198	73.66
	16-Jun	37	20	22	708							787	340.92
	18-Jun	11	1	75	66							153	37.64
	18-Jun	1	3	109	129							242	68.05
	20-Jun	8	22	0	52							82	22.88
	23-Jun	77	60	467	500							1,104	240.08
	25-Jun	518	466	1	196							1,181	241.67
	27-Jun	67	86	52	148							353	42.19
	1-Jul	37	42	60	333							472	143.67
	1-Jul	54	82	179	227							542	81.18
	3-Jul	4	4	0	41							49	19.26
	5-Jul	3	7	0	13							23	5.62
	7-Jul	1	2	1	0							4	0.82
	9-Jul	1	0	2	2							5	0.96

Appendix I, continued

		Sample Location / Depth										Total	
Year	Date	3/5	3/10	4/5	4/10	5	6	7	8	9	10	perch	SD
1989	3-Jun	1	0	8	5							14	3.70
	6-Jun	1	5	51	5							62	23.74
	13-Jun	34	0	454	161							649	206.47
	20-Jun	2	18	243	153							416	114.78
	26-Jun	1	4	1	307							313	152.51
	3-Jul	1	5	0	11							17	4.99
	10-Jul	1	0	0	0							1	0.50
	17-Jul	0	0	0	0							0	0.00
1990	30-May	0	0	0	0							0	0.00
	5-Jun	5	3	2	1							11	1.71
	11-Jun		6	48	19							73	21.50
	21-Jun	41	54	109	89							293	31.29
	25-Jun	27	69	40	1648							1,784	801.53
	2-Jul	4	1	107	488							600	230.66
	9-Jul	5	0	6	6							17	2.87
	16-Jul	0	0	1	0							1	0.50
	23-Jul	0	0	0	0							0	0.00
	31-Jul	1	0	0	0							1	0.50
1991	13-Jun	38	402	26	318							784	192.51
	17-Jun		6	31	68							105	31.19
	24-Jun	25	31	20	22							98	4.80
	2-Jul	2	2	2	0							6	1.00
1992	22-Jun	25	217	26	317							585	145.28
	25-Jun	20	174	15	303							512	138.05
	30-Jun	44	159	18	312							533	133.99
	6-Jul	0	0	2	82							84	40.68
	9-Jul	0	0	1	11							12	5.35
	15-Jul	0	0	0	0							0	0.00
1993	17-May												
	21-May												
	25-May												
	29-May												
	3-Jun-93												
	10-Jun-93												
	15-Jun-93												
	20-Jun-93												
	23-Jun-93												
	27-Jun-93												
	1-Jul-93												
	6-Jul-93												
	9-Jul-93												
	14-Jul-93												
	19-Jul-93												
	22-Jul-93												

1987 UPDATE
TO NO (3)
TRANSECT

Appendix II. Summary of young-of-year yellow perch sampling, 1987-1992, using bottom trawls.

Date	Trawl #	Time (min)	Distance (nm)	Speed (kt)	Depth (m)	# Fish caught	CPE (fish/1000m^2)
1987							
8/7/87	1	10	0.38		5	127	59.2
	2	9	0.38		4.5	58	27
	3	10	0.47		10	0	twisted
	4	10	0.56		10	0	0
	5	10	0.5		2.7-4.3	92	32.6
	6	10	0.45		3	114	44.9
9/9/87	1	10	0.38	2.5	5.1	122	56.8
	2	10	0.42	2.5	8.3	6	2.5
	3	10	0.42	3	1	1	0.4
	4	10	0.48	3	5.1	108	39.8
	5	10	0.51	3.8	8	0	0
	6	10	0.48		2.2	461	170
10/20/87	1	8	0.29		3.8-8.6	0	tangled
	2	9	0.36		3.3-10	308	151.5
	3	10	0.36		4.7-8.3	77	37.9
	4	3	0.13		5.5	0	tangled
	5	10	0.4		5.5-4.1	249	110.2
1988							
8/30/88	1	5	0.25	3	2.8-4	719	509.2
9/22/88	1	5	0.25	3	3.2	16	11.3
	2	5	0.29	3.5	3	8	4.9
	3	6	0.34	3.4	4.8	20	10.4
	4	5	0.3	3.6	5	13	7.7
	5	10	0.57	3.4	10	0	0
1989							
8/1/89	1	10	0.36	3.5	5	1	0.3
	2	10	0.61	4	1.5-2.5	0	0
	3	10	0.49	4	5	2	0.5
	4	10	0.6	3.3	5	1	0.2
8/10/89	1	10	0.5	4.5	5	0	0
	2	13	0.89	4-4.5	8	0	0
8/15/89	1	10	0.72	4.5	2	0	0
	2	10	0.74	4.5	3	0	0
8/16/89	1	10	0.67	4	10	0	0
	2	10	0.69	4.5	2	12	1.9
	3	10	0.67	4.4	3	1	0.2
8/21/89	1	7	0.4	4-4.5	2	1	0.3
	2	10	0.5	4.5-5.0	8	0	0
	3	7	0.51	4-4.5	6.5	0	0
	4	9	0.53	4.5	4	0	0
	5	10	0.58	3.5	2	131	25
9/5/89	1	10	0.62	3-4.5	2	255	45.5
	2	6	0.5	4	5	0	0
	3	7	0.5	3.5-4	5	0	0
	4	9	0.55	4-4.5	2	///	///

Appendix II. Continued.

Date	Trawl #	Time (min)	Distance (nm)	Speed (kt)	Depth (m)	# Fish caught	CPE (fish/1000m^2)
9/8/89	1	10	0.56	3.6	1.5	97	19.2
	2	7	0.5	4	1.5	17	3.8
	3	10	0.52	3.7	3.5	69	14.7
	4	5	0.3	3.5	3	23	8.5
	5	10	0.47	3.6	6	0	0
	6	10	0.65	3.5	5	0	0
	7	10	0.44	3	10	0	0
	8	10	0.56	4	1.5	198	39.1
1990							
8/2/90	1	9	0.47	3.1	7	0	0
8/7/90	1	6	0.42	4.2	1.5-2.5	0	0
	2	8	0.49	4.1	3.5	1	0.2
	3	8	0.49	3.3	2.5-3	0	0
	4	5	0.33		5.5	0	0
	5	10	0.57	4.4	4	6	1.2
8/9/90	1	9	0.5	4	4	4	0.9
	2	8	0.46	4	3	4	1
	3	8	0.5	4	5.5	1	0.2
8/14/90	1	7	0.5	4.5	5	2	0.4
	2	8	0.6	4.8	3	0	0
	3	9	0.6	4	7	0	0
	4	9	0.58	3.7	9	0	0
	5	9	0.55	4	11	0	0
8/22/90	1	8	0.5	4	11	0	0
	2	8	0.5	4	11	0	0
	3	7	0.5	3.9	9	0	0
	4	8	0.5	4	9	0	0
	5	7	0.5	4	7	0	0
	6	8	0.5	4	7	0	0
	7	8	0.5	3.9	5	1	0.2
	8	9	0.5	4	5	0	0
	9	6	0.45	4	3	2	0.5
	10	7	0.5	4	3	0	0
8/29/90	1	7	0.5	4.4	3.5	0	0
	2	7	0.5	4.4	5	0	0
	3	8	0.5	4.2	7	0	0
	4	1.5	\\	4.3	7		not fishing correctly
	5	11	0.5	3	7	0	0
	6	12	0.5	2.5	9	0	0
8/31/Q9	1	11	0.53	2.9	7	0	0
	2	5	0.17	3.5	5	0	0
	3	8	0.5	4.2	3.5	1	0.2
	4	7	0.5	4.1	2.5-3	0	0
9/4/90	1	7	0.5	4	5	0	0
	2	8	0.5	4.1	3.5	0	0
	3	16	0.5	2.6	7	0	0
	4	11	0.5	2.6	9	0	0
	5	16	0.5	2.5	11	0	0
	6	9	0.5	3.9	3.5	0	0

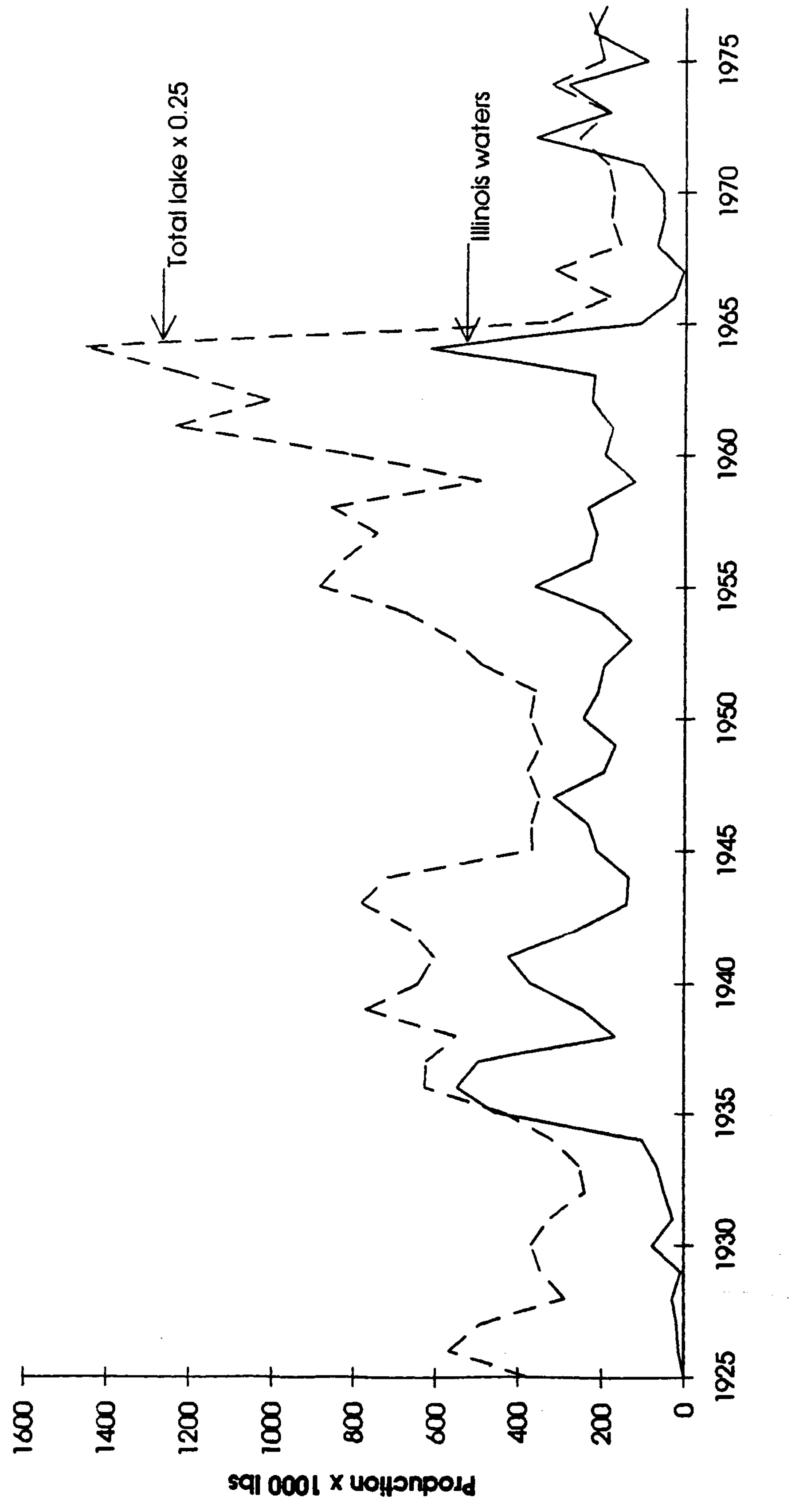
Appendix II. Continued.

Date	Trawl #	Time (min)	Distance (nm)	Speed (kt)	Depth (m)	# Fish caught	CPE (fish/1000m^2)
9/6/90	1	6	0.5		3	0	0
	2	9	0.5		5	0	0
	3	7	0.5		4	0	0
	4	7	0.5	4.2	3	0	0
	5	9	0.5	3.8	3	0	0
9/10/90	1	8	0.5	4	2-3.0	12	2.7
	2	7	0.5	4.3	4.5-5	1	0.2
9/12/90	1	7	0.5	4.1	2.5-3	20	4.4
	2	8	0.5	4.1	2.5-3	24	5.3
	3	7	0.5	4.1	5	0	0
	4	9	0.5	4.1	5	0	0
	5	7	0.5	4.4	3	0	0
	6	8	0.5	4.2	2.5	62	13.7
	7	6	0.5	4.1	2.5	41	9.1
9/19/90	1	7	0.5	4.5	3	0	0
	2	6	0.5	4.7	2.5	0	0
	3	7	0.5	4.5	5	0	0
9/20/90	1	7	0.5	5	2.5	0	0
	2	\\	0.5	4	4	0	0
	3	7	0.5	4	5	31	6.9
	4	10	0.5	3.8	6-7.0	15	
	5	11	0.5	3.4	7	0	0
	6	10	0.5	3	10	0	0
	7	7	0.5	4	5	0	0
9/24/90	1	9	0.5	3.9	2.25	0	0
	2	9	0.5	4	3	0	0
	3	9	0.5	4	5	0	0
9/27/90	1	8	0.5	4	2.25	0	0
	2	8	0.5	4	3.25	0	0
	3	8	0.5	3.7	5	0	0
10/15/90	1	5	0.25	2.8	2.25	0	0
	2	11	0.5	2.8	5	0	0
	3	10	0.5	2.9	4	5	1.1
	4	10	0.5	3	4.5	0	0
	5	\\	\\	3	3.5	5	snagged
	6	9	0.5	3	3.25	0	0
10/16/09	1	11	0.5	3.2	4.5	4	0.9
	2	10	0.5	2.7	4.5	3	.7 snagged
1991							
10/1/91	1	10	0.75	4.7	5	0	0
	2	10	0.78	4.9	3	0	0
	3	\\	0.8	5	3-5.0	0	0
	4	13	1	4.8	5-7.0	0	0
	5	14	1	4.5	6-1.5	0	0
	6	10	0.75	4.4	7.5	0	0
	7	12	0.9	4.2	8	0	0
10/23/91	1	\\	0.8	4.8	4	0	0
	2	\\	0.8	4.8	6	0	0
	3	\\	1	4.7	2-3.0	0	0
	4	\\	0.8	4.5	8	0	0

Appendix II. Continued.

Date	Trawl #	Time (min)	Distance (nm)	Speed (kt)	Depth (m)	# Fish caught	CPE (fish/1000m^2)
1992							
8/25/92	1	8	0.5	3.5	6	0	0
	2	18	0.76	3.5	10	0	0
	3	17	1	3	11	0	0
9/18/92	1	9	0.6	4.7	6	0	0
	2	7	0.5	4.1	3	0	0
	3	\\	\\		2	Broke off	
	4	9	0.6	4	2	0	0
	5	11	0.75	3.7	10-11.0	0	0
10/7/92	1	7	0.5	4.3	6-7.5	0	0
	2	6	0.51	4.5	5	0	0
	3	10	0.75	4.8	2-3.0	0	0
	4	10	0.75	4.7	4-5.0	0	0

Figure 1. Production of yellow perch (x 1000 lbs) from commercial fishing in Lake Michigan. (data from Baldwin et al. 1979)



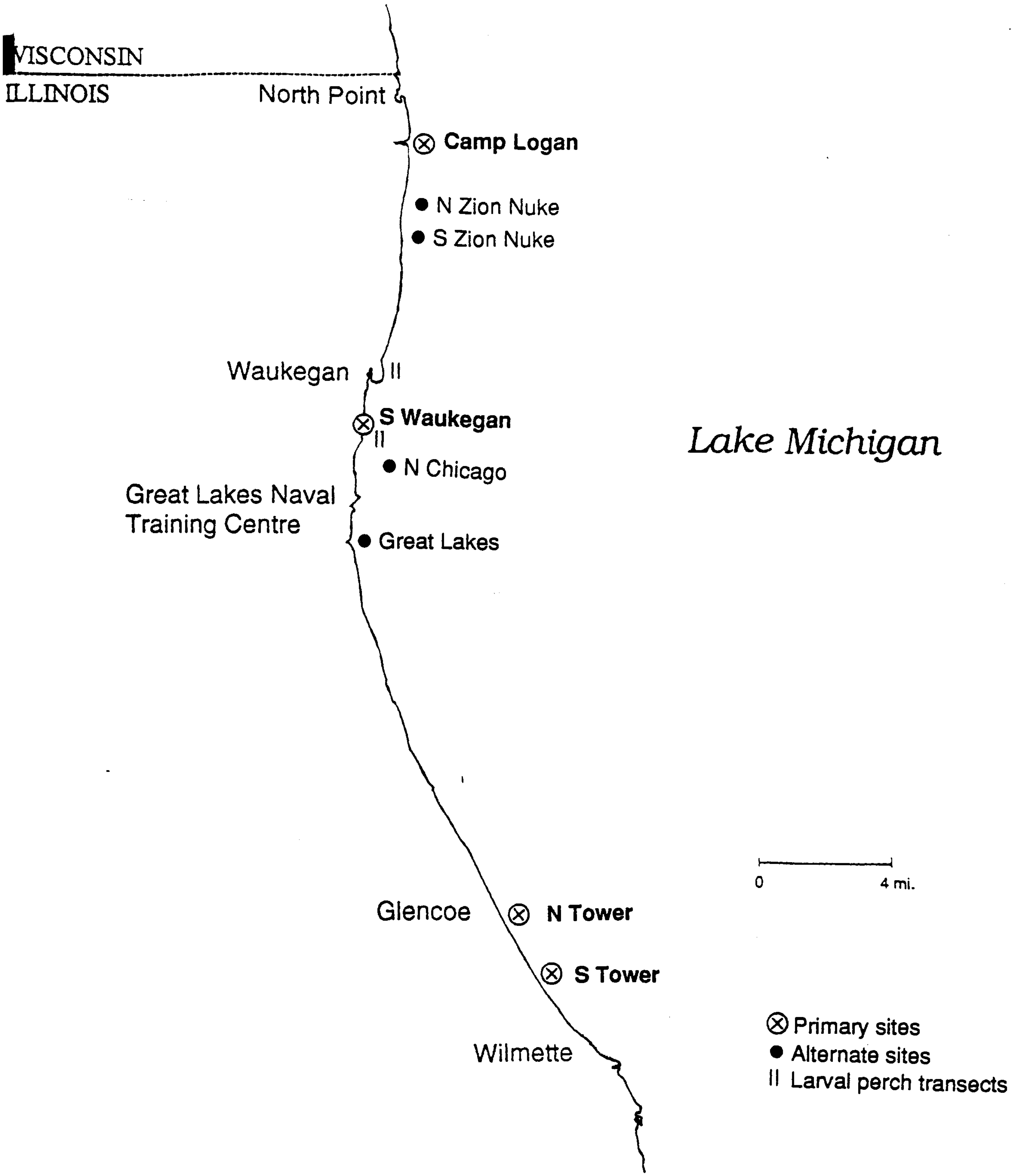


Figure 2. Sampling sites for yellow perch in south-western Lake Michigan.

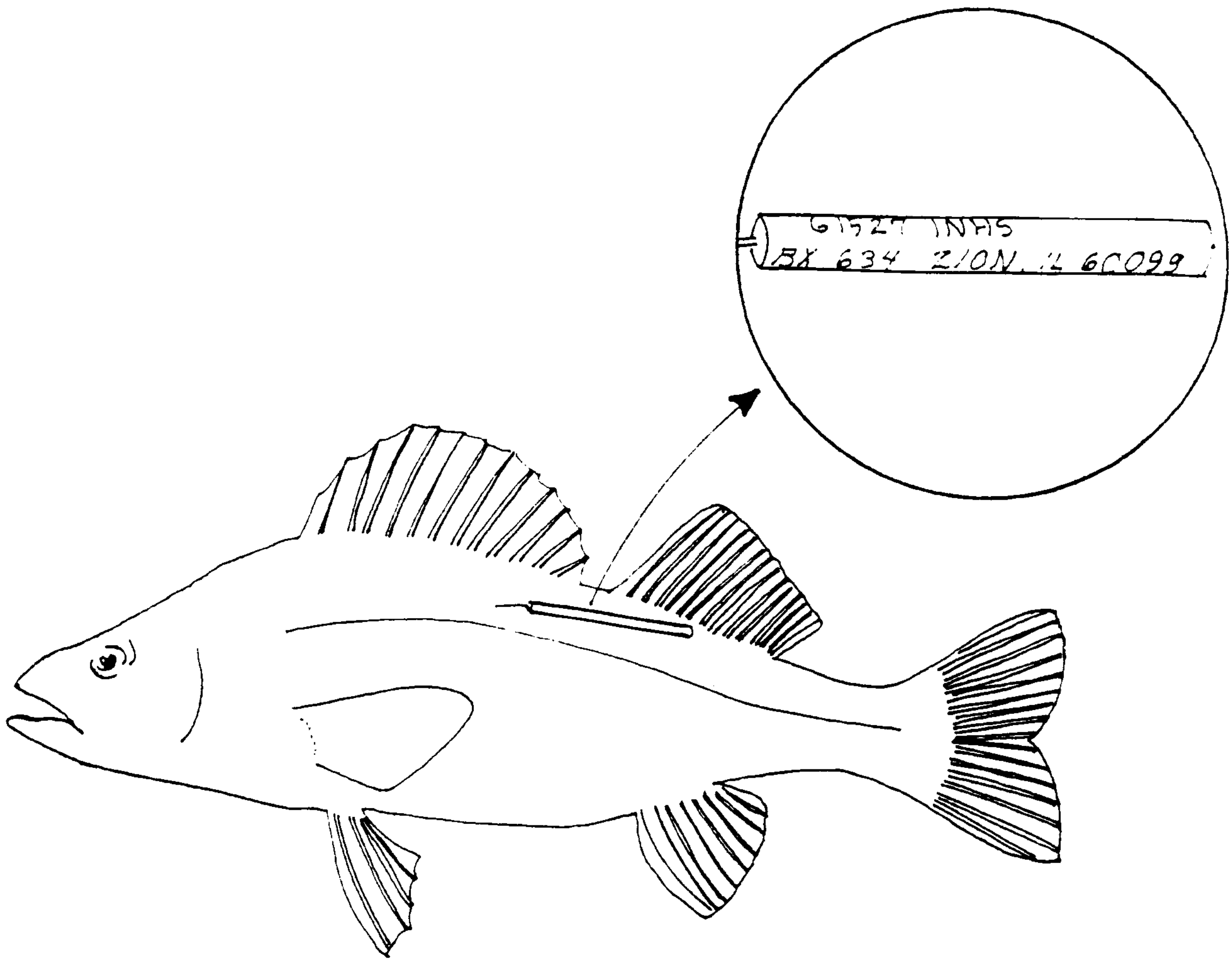


Figure 3. Location of Floy tag placement on yellow perch.

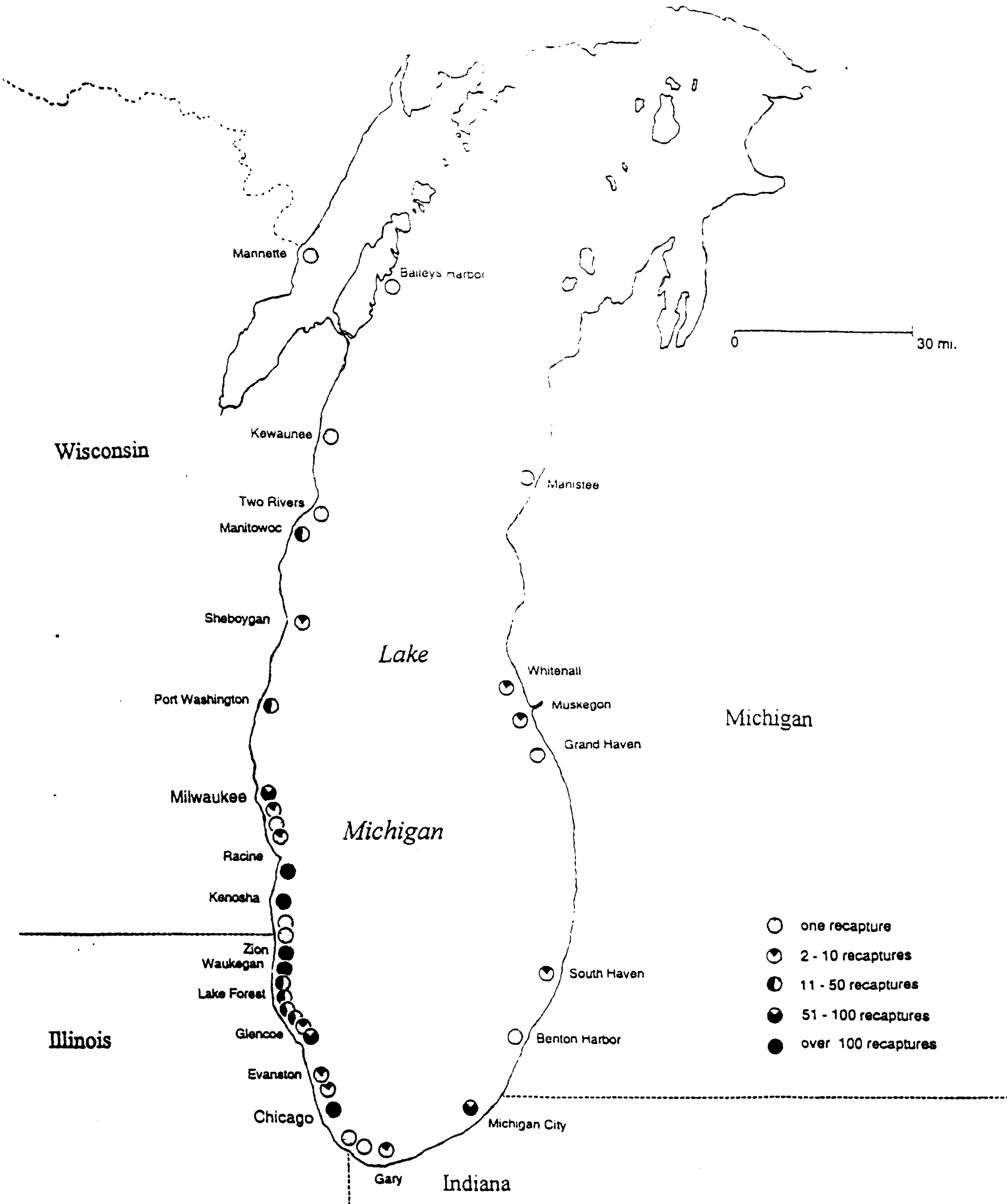
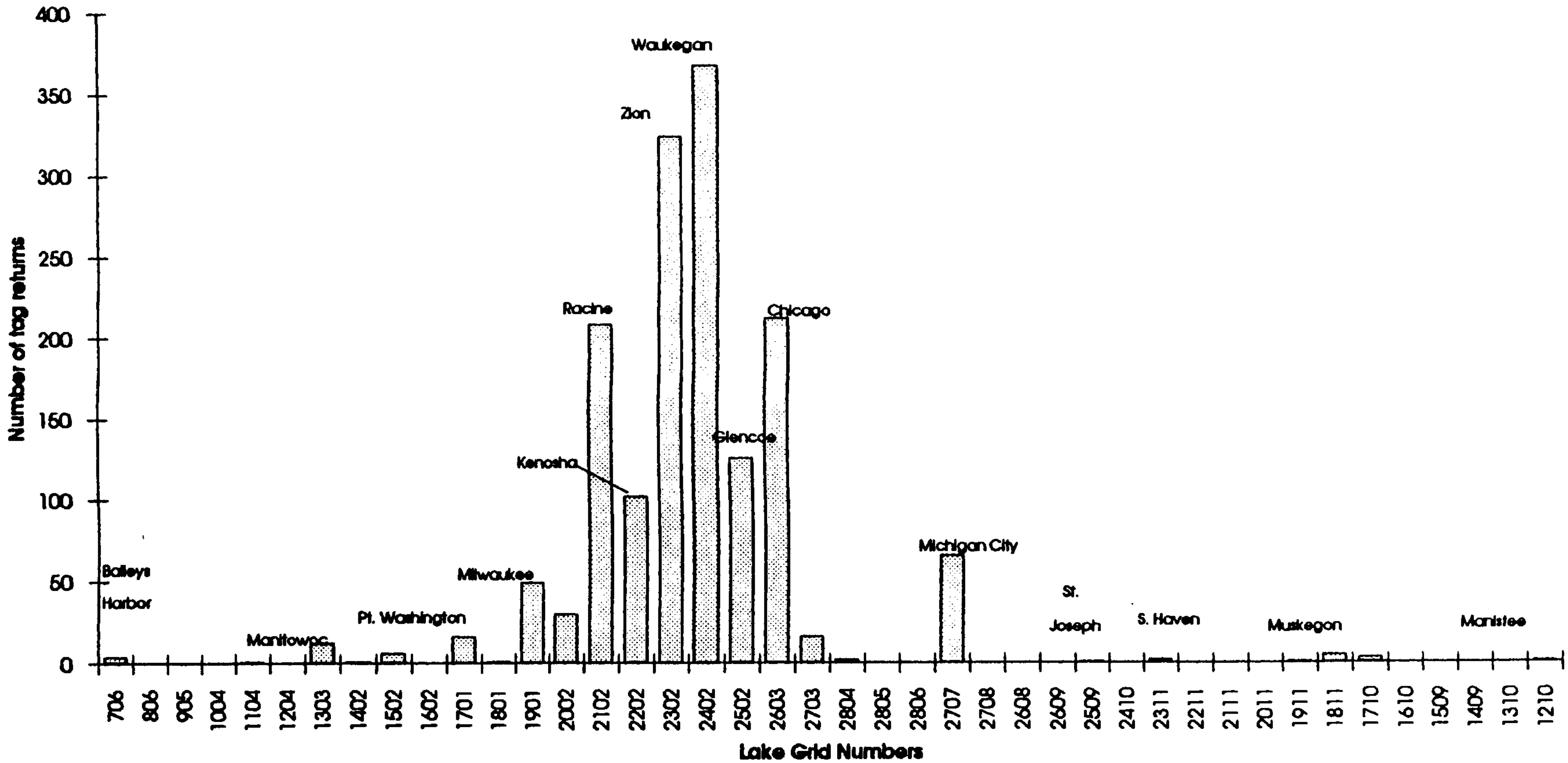


Figure 4. Map of recapture sites of yellow perch tagged in south-western Lake Michigan.

Figure 5. Location of yellow perch tag returns from all years of the study, summarized by the lake grid in which they were recaptured



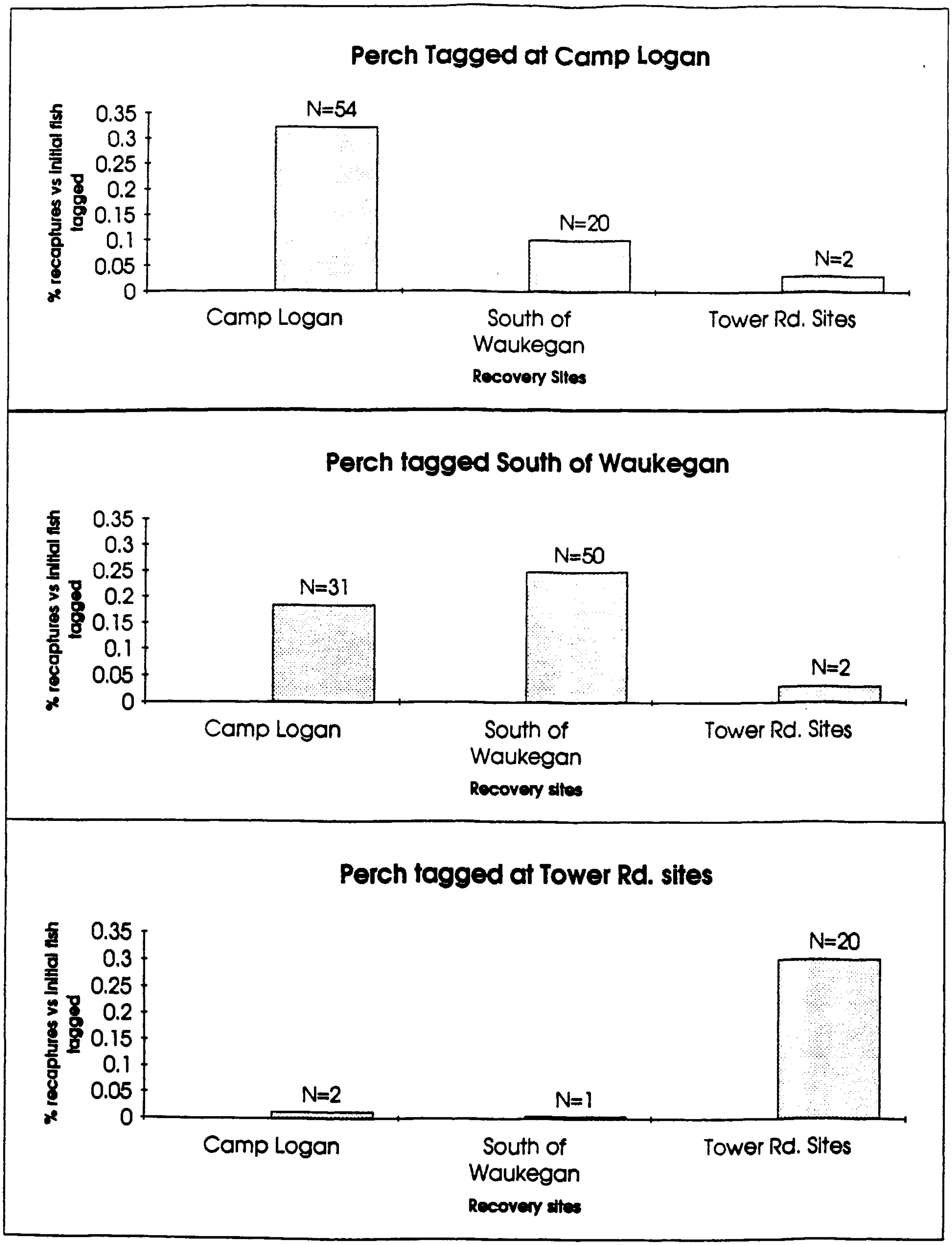


Figure 6. Proportion of tagged yellow perch recovered at each site relative to where they w tagged. Fish were recovered using fyke nets in spring,1990-1992.

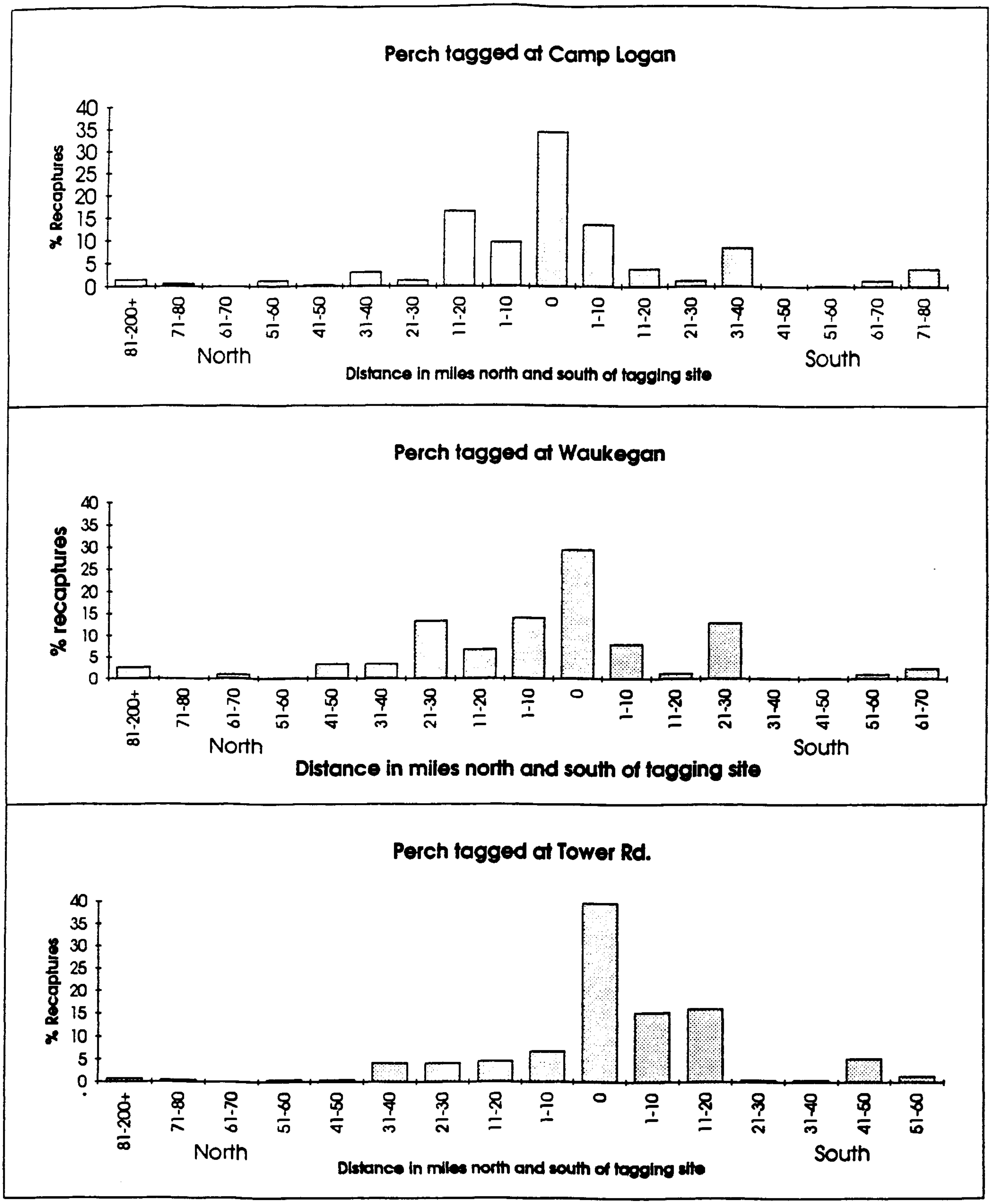


Figure 7. Recapture of yellow perch tagged at each major site, shown as distance between tagging and recapture sites. Data are summarized from all years and all recapture sites.

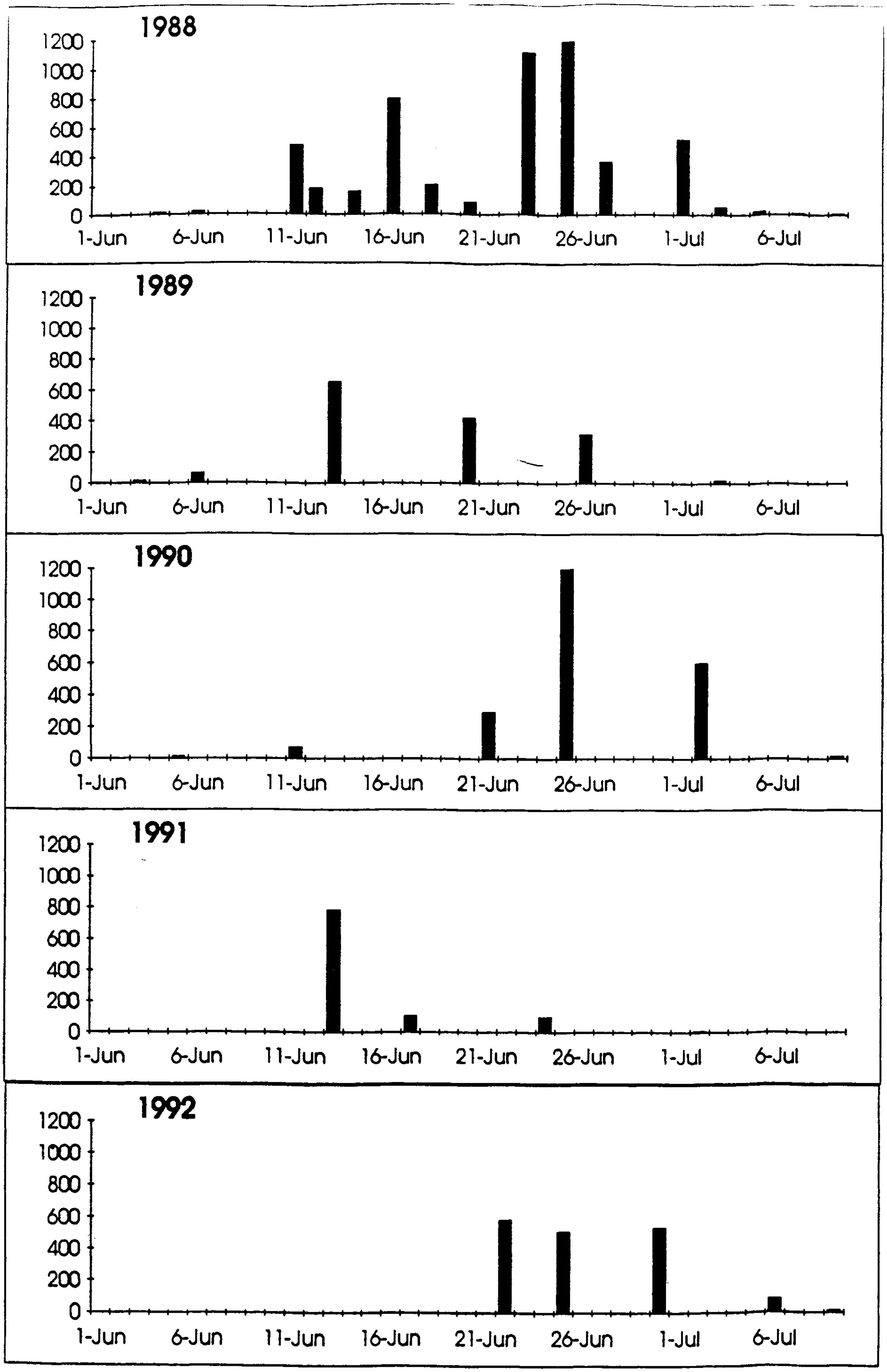


Figure 8. Larval yellow perch catches in 1988 - 1992.

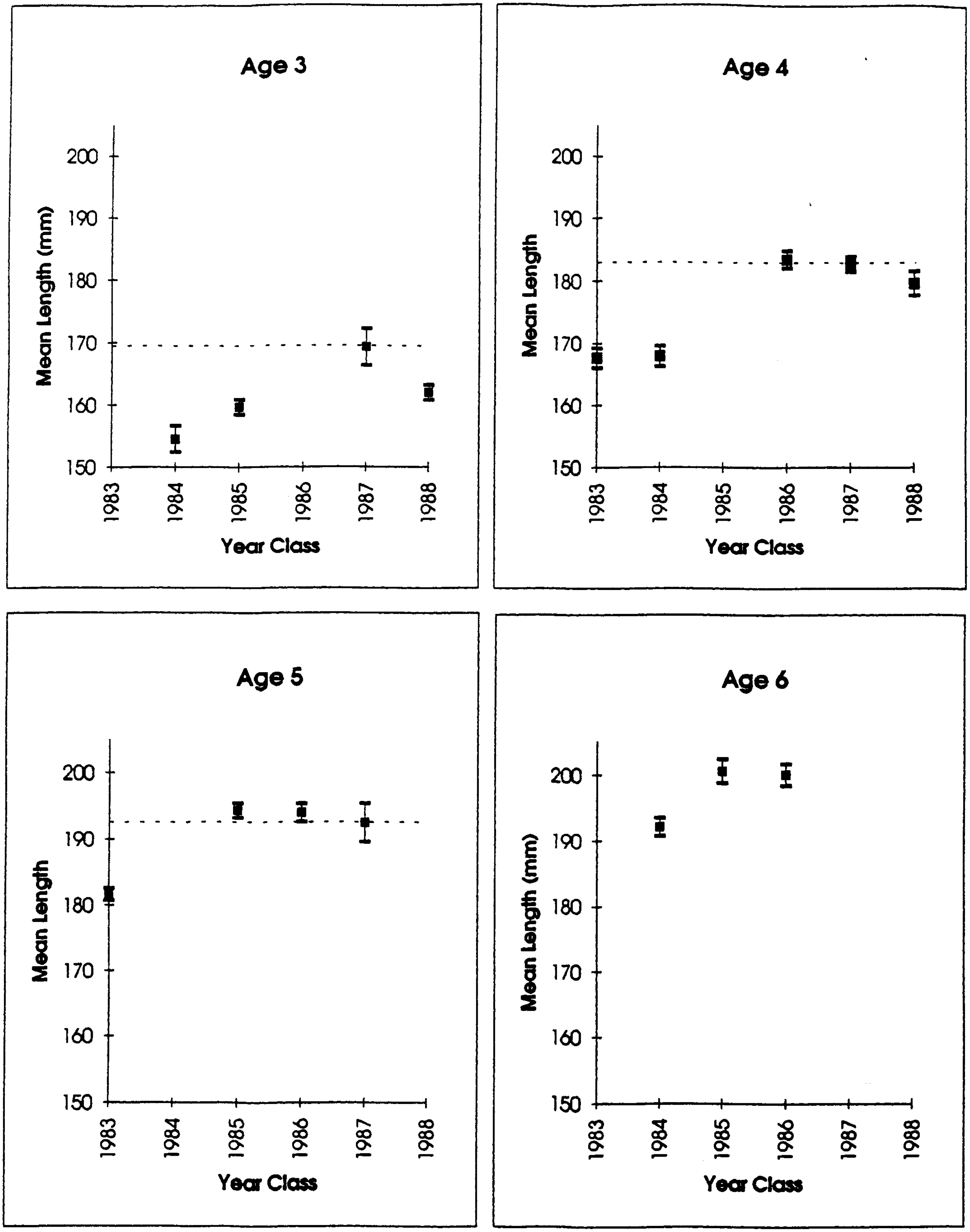


Figure 9. Mean length of spring sampled male yellow perch by year class. No data were available in years when only fall sampling was done. Reference line is drawn through the 1987 year class.

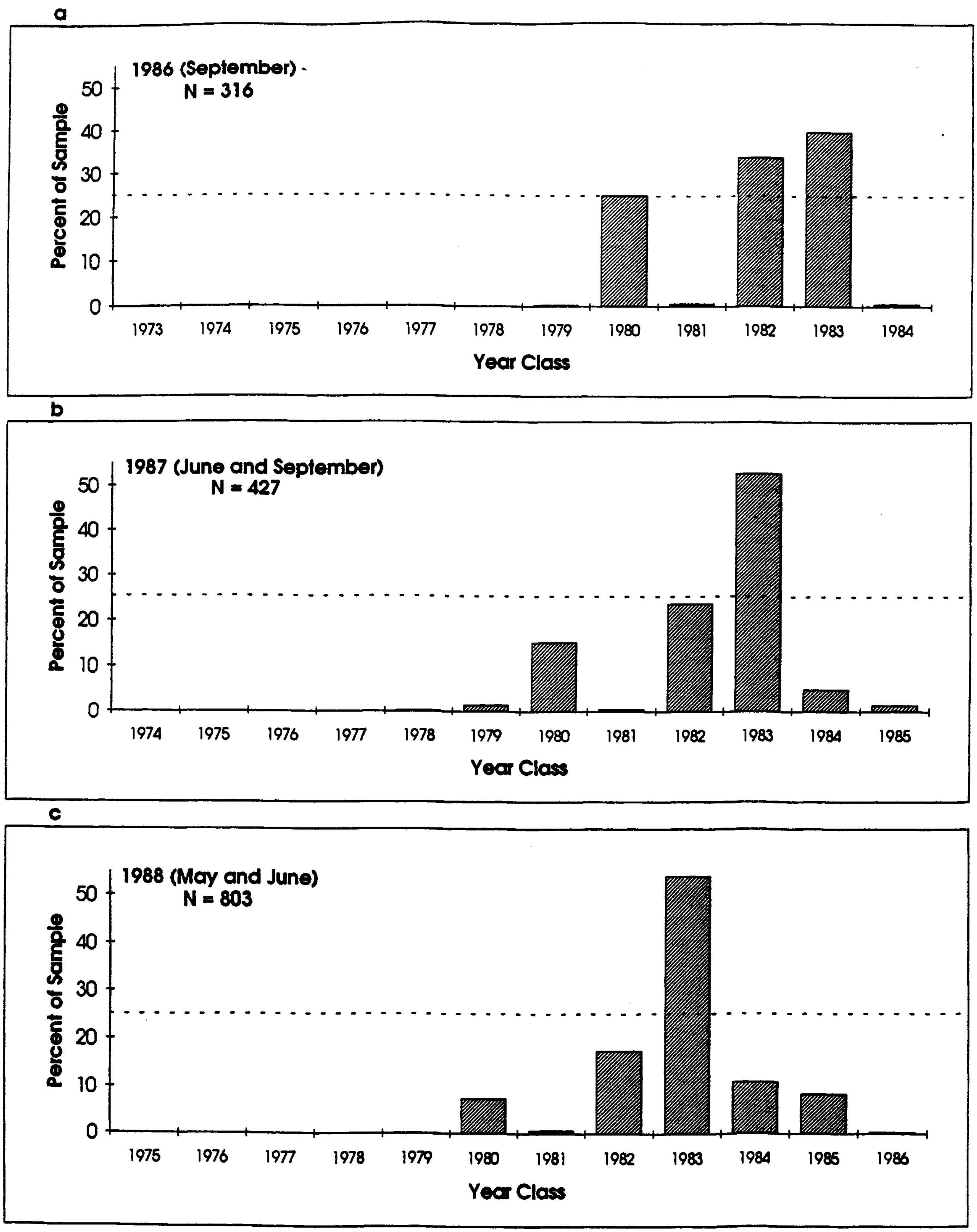


Figure 10 (a-c). Year class frequency of yellow perch sampled in gill nets at all sites.

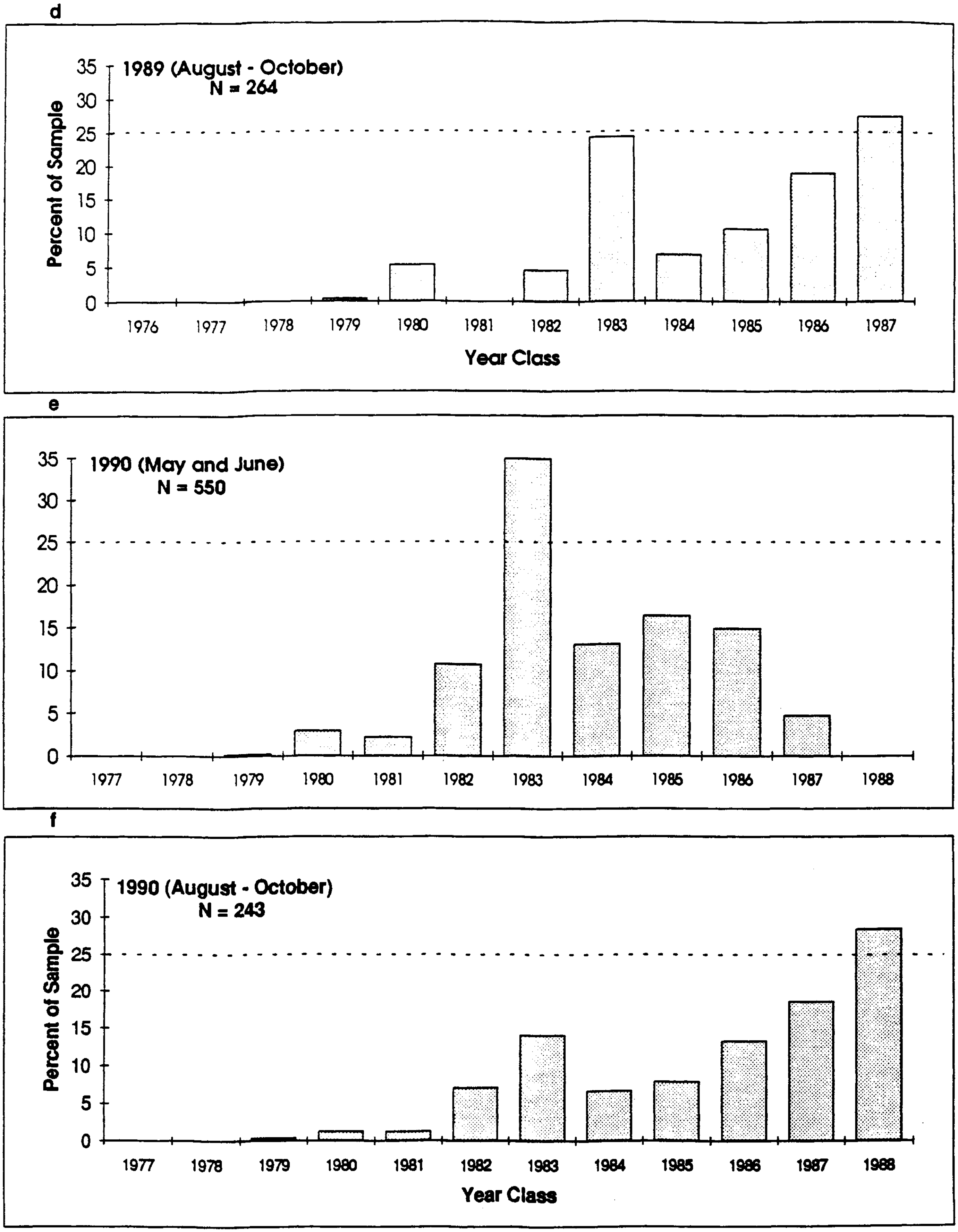
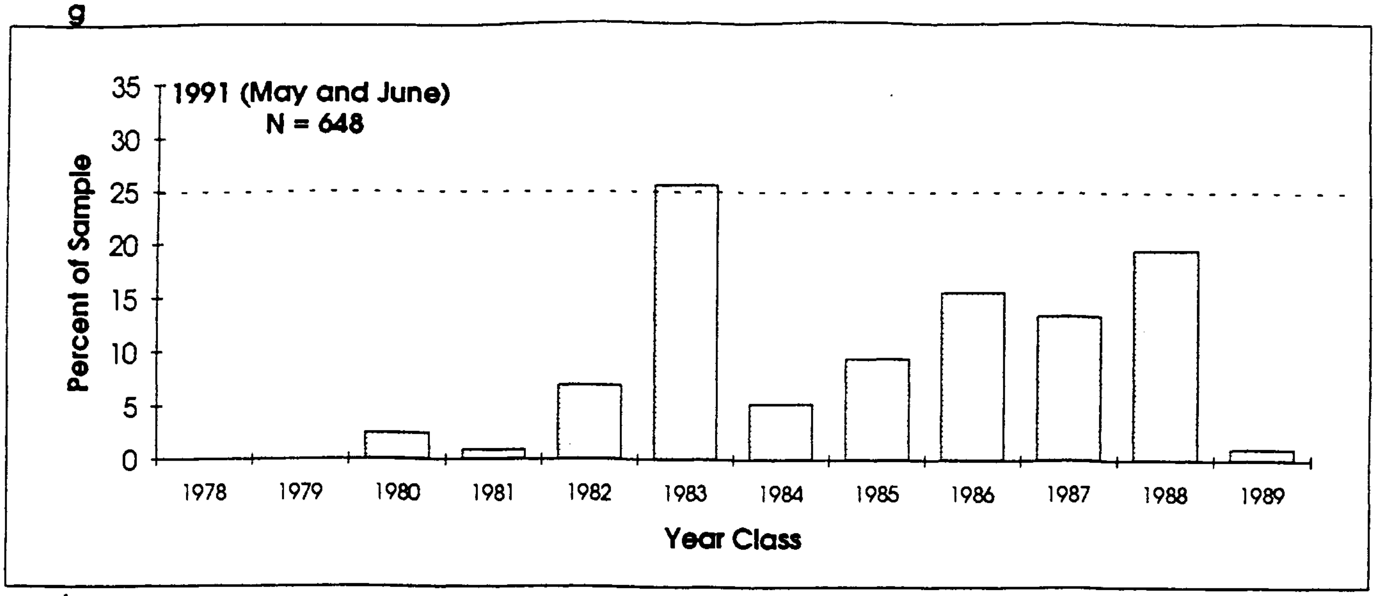


Figure 10 (d - f). Year class frequency of yellow perch sampled in fyke nets at all sites.

g



h

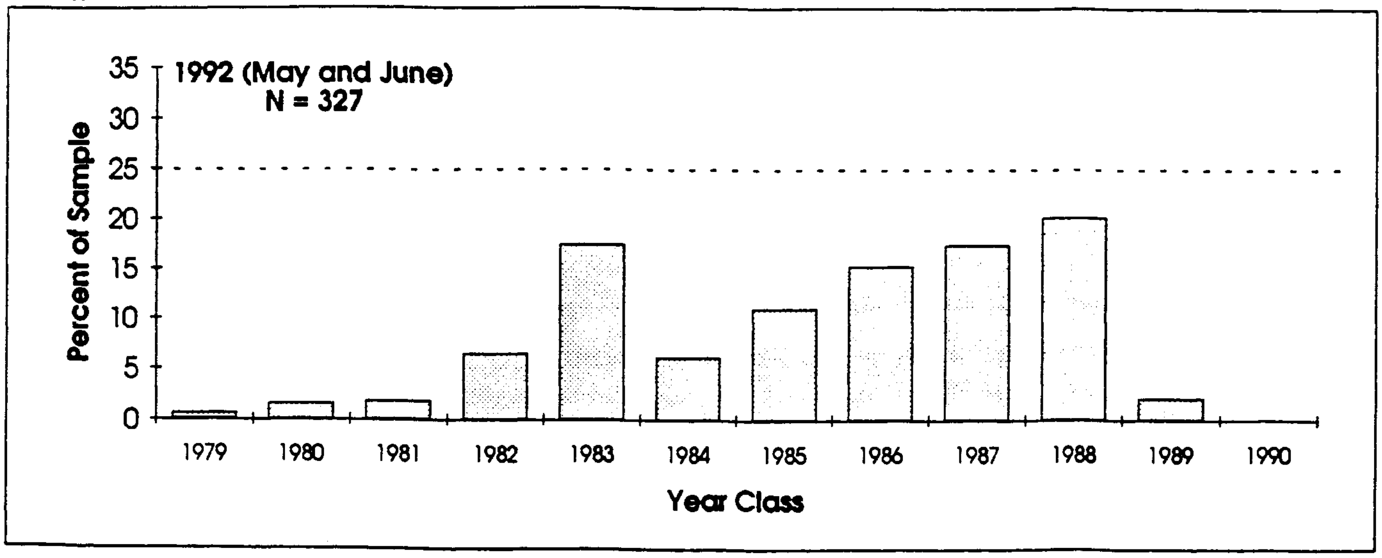


Figure 10 (g - h). Year class frequency of yellow perch sampled in fyke nets at all times.

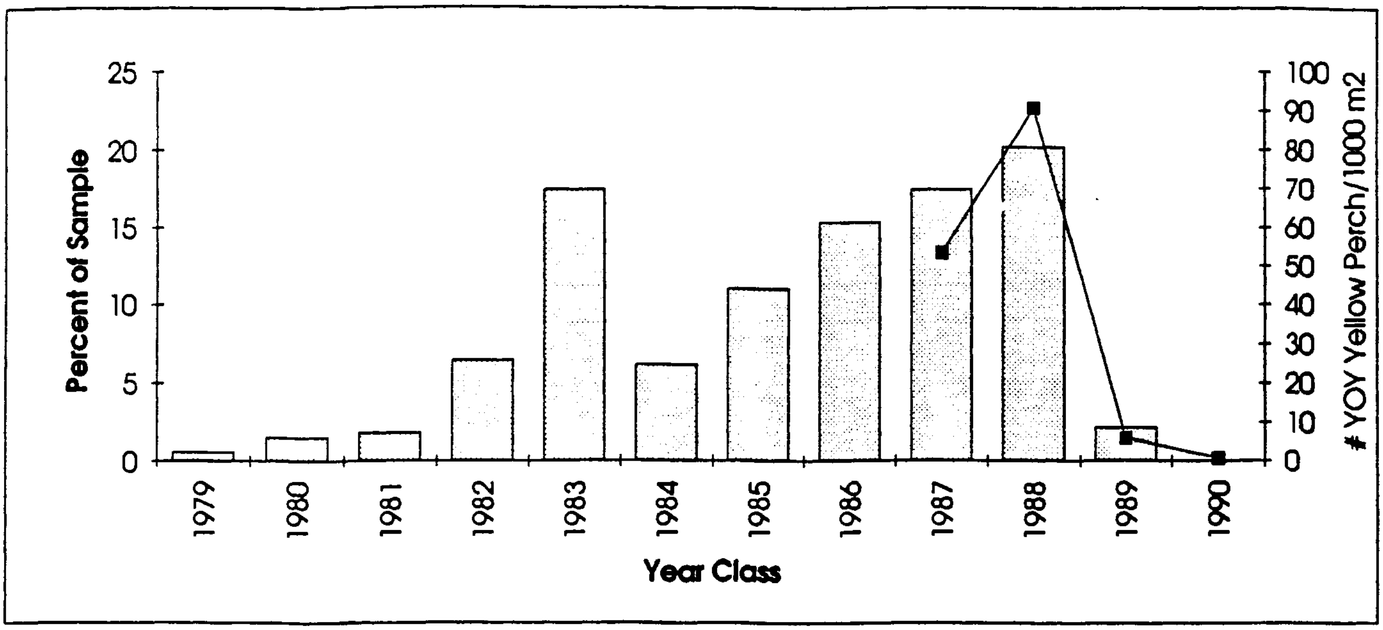


Figure 11. Year class frequency for yellow perch from 1992 samples and trawl CPUE's for YOY yellow perch 1987-1990.